Фізика аеродисперсних систем. – 2023. – № 61. – С.131-141

ЕЛЕКТРОФІЗИКА

УДК: 533.9, 524.1

Doikov D.M.[1]***, Doikov M.D.***[2]

1 Odessa National Maritime University, dmitro.doikov@mail.bg
2 Plovdiv University Paisii Hilendarski, Bulgaria, marik.doikov@gmail.com

Positron spectroscopy of γ-flashes in the earth atmoshear

The registration of the fast thermonuclear transformation in Earth's atmosphere is considered. One of them is γ-flashes from thunder lightning. The atmospheric chemical composition and bound conditions in the thunder lightning plasma tubes were associated with thermonuclear transformation. Nuclear reaction channel cross-sections were selected for the calculation of the γ-ray spectra. It was found that under existing conditions the γ-spectrum is formed due to the formation of unstable proton-excess nuclei with their further decay. It has been shown that electron-atom collisions are important and only initiate the formation of proton and fully ionized He (after sufficient acceleration, we call them α-particles) current flows. In this case, protons and α-particles initiate nuclear transformation after collisions with atmospheric He, C, N, O, and Ne atoms. The time scale of γ-fluorescence is estimated and related to observation with traditional γ-ray detectors. Separately calculated contribution of pollution admixturefrom dust into γ-spectra.

Keywords: *ionosphere plasma, plasma with CDP inlighting current tubes, local electrical field Earth atmospheres, γ-flash.*

1. Introduction. Five years ago, in 2017 near Japan's atomic station accidentally has been registries shot γ- flash by lightning. In previous periods these devices detected only integral flows of the γ-rays. The installation of high-resolution spectrographs made it possible to closely monitor the technology of nuclear energy production. In this case, the main range of their energies belongs to the interval 0.1 - 150 MeV. In modern nuclear physics, his name is "soft" γ-rays. However, γ-flash mainly were in the left wing of the marked range, where the accuracy of recording the γ-spectrum is low. The time resolution of the detectors did not allow us to trace the dynamics of the process. It became clear that lightning had to be investigated with high-speed soft γ-range detectors. In this paper, we will present the parameters of the detectors we are developing and the physical phenomena that lead to the formation of nuclear transformation processes in the lightning current column. In [1,2] has been proposed positron spectroscopy of the fast processes in the astrophysical systems which contain cool, low-temperature plasma in an expanded blast wave envelope after a supernovae explosion in 1987 (SN 1987A). Unstable isotope decays inject positrons into cool gas and initiate annihilation with the formation of the γ-quants with energy E_γ ($E_\gamma = 0{,}511 MeV$)

The registration of this and accompanying quants allows you to accurately identify the channel of nuclear transformations, to estimate the time frame of fast processes. Detectors from Japan's atomic station registered annihilation quants. The ab-

DOI:10.18524/0367-1631.2023.61.290221

sence of such measurements in the past can only mean the low sensitivity of the detectors. The study of lightning is of interdisciplinary importance and combines the possibility of studying the unique conditions of atmospheric plasma. The three-hundred-year history of his study made it possible to create a general physical picture of the process of formation of a strong lightning electric discharge [3]. The region of a strong field exists only at the channel head, and in the length of created plasma behind the head, it is incomparably weaker. The local strength electrical field in upper point is $E \approx (1-3)\cdot 10^6 V/m$. The free path length in the channel head is $l \approx 2{,}9\cdot 10^{-6}m$. In these condition electrons accelerate to relativistic energies and initiate full ionization of the atmospheric gas. In this case, electrons cannot directly create γ-quants. To start nuclear transformations, high-energy protons, and helium nuclei are needed only after impact electron ionization. The very fact of the formation of γ-quanta confirms the formation of high-energy protons and helium nuclei. In section 2 we consider possible canals of the nuclear transformation in the frame of the existing chemical composition and energies of the electrical field. Section 3 are presented γ-spectra from lightning electric discharge formed by the cumulative result of all channels of nuclear transformations. The main results of these sections are the final structure of γ-spectra, and time intervals for his formation. After nuclear collisions, the possible interval of the γ-ray energies is (0,1 – 10) MeV. At present time has been registered annihilation line

2. The possible nuclear processes in the lightning channel head.

2.1 Proton projectivity. The mean time $\langle t\rangle$ between projective protons and atmospheric molecules collisions is $\langle t\rangle_p \approx 0{,}14\cdot 10^{-10}s$ and α- particles is $\langle t\rangle_p \approx 0{,}56\cdot 10^{-10}s$. Partial velocities are is in power$\langle v\rangle_p \approx 2\cdot\langle v\rangle_\alpha \approx 10^4 m/s$. The necessary velocities for nuclear transportations are in power $\langle v\rangle_p \approx 3{,}46\cdot 10^7 m/s$, $\langle v\rangle_\alpha \approx 1{,}73\cdot 10^7 m/s$ Then in the lightning channel head full distances of proton and α-particle consists 100-200 m. Mean lightning channel length is L ≈1000 m from observation. This is γ-ray formatıon point in the lightnings current tube. The variety of forms of lightning suggests that there is a similar variety of boundary conditions for their formation. For this, it is necessary to carry out a separate analysis, which is beyond the scope of this article. After collision ionization between electrons, atoms and molecules begins movement of protons and helium nuclear. Proton and α-particle collisions with He, C, N, O, Na, Ar, Ne atoms how source of the observed γ-ray ın lightnings will consider in this chapter. The cross section of collisions of the energetic proton and α-particles with atoms of Earth atmosphere present possibility of γ-ray spectra. detailed data on the structure of possible γ-radiation make it possible to quantify the spectroscopic features of the considered physical system. The choice of channels for nuclear transformations will be divided into channels with the participation of protons and α-particles presented in formula (1). The cross sections are in mbn ($10^{-27}cm^2$) and selected from [8].

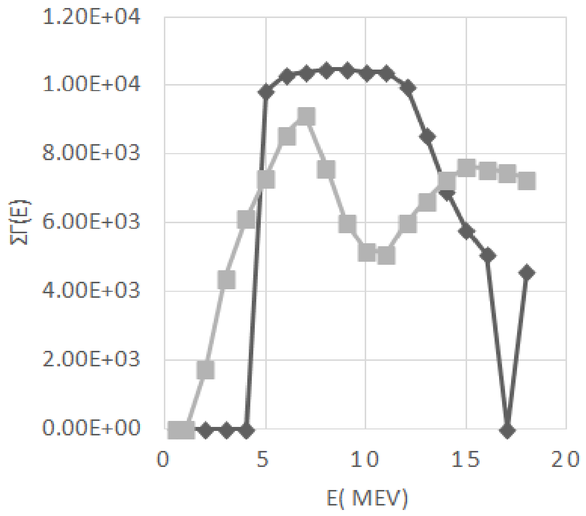

Fig.1 Cross section ΣΓ(E) of γ-emission
♦ - p+$^{12}_{6}C$-->γ +..., ■ - p+$^{13}_{6}C$-->γ +...

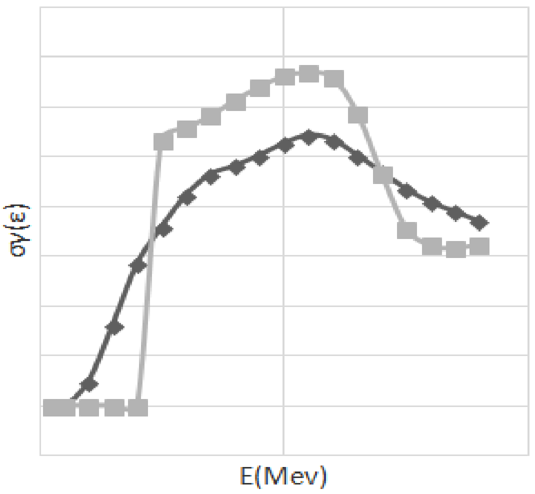

Fig.2 Cross section ΣΓ(E) of γ-emission
♦ - p+$^{14}_{7}N$-->γ +..., ■ - p+$^{16}_{8}O$-->γ +...

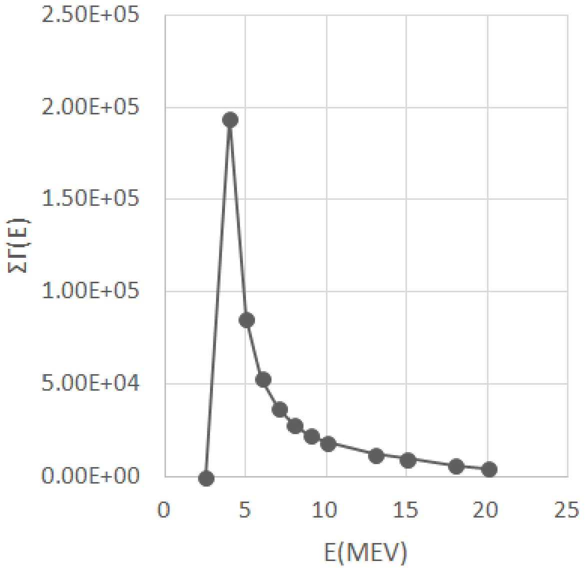

Fig.3 Cross section ΣΓ(E) of γ-emission p+$^{4}_{2}He$-->γ +...

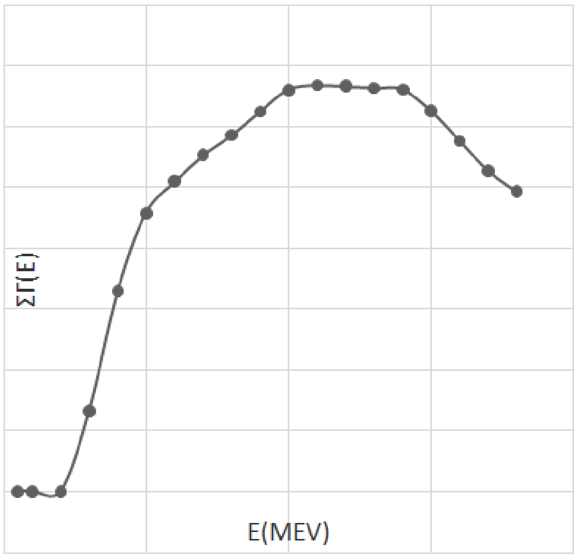

Fig.4 Cross section ΣΓ(E) of γ-emissionp+$^{23}_{11}Na$-->γ +...

$$\begin{cases} p+{}^{12}_{6}C \to {}^{12}_{6}C^{*} \to \gamma + {}^{12}_{6}C + \cdots \\ p+{}^{13}_{6}C \to {}^{13}_{6}C^{*} \to \gamma + {}^{13}_{6}C + \cdots \\ p+{}^{14}_{7}N \to {}^{14}_{7}N^{*} \to \gamma + {}^{14}_{7}N + \cdots \\ p+{}^{16}_{8}O \to {}^{12}_{6}C^{*} \to \gamma + {}^{12}_{6}C + \cdots \\ p+{}^{4}_{2}He \to {}^{4}_{2}He^{*} \to \gamma + {}^{4}_{2}He + \cdots \\ p+{}^{23}_{11}Na \to {}^{23}_{11}Na^{*} \to \gamma + {}^{23}_{11}Na + \cdots \end{cases} \quad (1)$$

Presented in Fig.1 – Fig.3 allow us to conclude the total cross sections for γ-radiation of proton – atoms collisions. The main contribution from targets nucleus in Earth atmosphere produce from $^{13}_{6}C, ^{14}_{7}N$ *and* $^{4}_{2}He$. The chemical composition of elements in Table 1 shows that these elements are importance for γ-spectroscopy of the lightnings.

Table 1. Gas composition in Earth's atmosphere.

Gas	The volume concertation %	Molar mass in a. m. u
N_2	78.084	28.0134
O_2	20.9476	31.9988
Ar	0.934	39.948
CO_2	0.0314	44.00995
Ne	0.001818	20.179
He	0.000524	4.0026
H_2O	0.1(clouds)	18.01528

2.2 Alfa-particle projectivity. Table 1 shows the volume concertation of He. Despite the low concentration, the formation and acceleration of its ions play an important role in the formation of impact-induced γ-radiation [8]. Average acceleration distances are much higher. They have large ionization losses and lower accelerations. Therefore, the localization of the formation zone of the induced γ-quanta is lower along the lightning trunk. As will be seen from the graphs below, γ-radiation induced by α-particles has characteristic spectra and allows for quantitative analysis of the lightning current shaft. We will present spectroscopy properties in the next nuclear transformation reaction. As in the previous section, decay products that are not important for the topic of this article are shown as ellipsis. In presented in the series of nuclear canals (2) The collisions energies of the α-particles are well for projectivity. The geographical localization of thunderclouds imposes changes in the physical conditions for the formation of lightning. This circumstance determines our interest in the collision of protons and α-particles by Na and Cl atoms. The zone of the first registration of γ-bursts from lightning lay near the coastal zone. The detectors themselves were intended for γ-monitoring of nuclear power plants.

$$\begin{cases} \alpha + {}^{12}_{6}C \rightarrow {}^{12}_{6}C^{*} \rightarrow \gamma + {}^{12}_{6}C + \cdots \\ \alpha + {}^{13}_{6}C \rightarrow {}^{13}_{6}C^{*} \rightarrow \gamma + {}^{13}_{6}C + \cdots \\ \alpha + {}^{14}_{7}N \rightarrow {}^{14}_{7}N^{*} \rightarrow \gamma + {}^{14}_{7}N + \cdots \\ \alpha + {}^{16}_{8}O \rightarrow {}^{12}_{6}C^{*} \rightarrow \gamma + {}^{12}_{6}C + \cdots \\ \alpha + {}^{4}_{2}He \rightarrow {}^{4}_{2}He^{*} \rightarrow \gamma + {}^{4}_{2}He + \cdots \\ \alpha + {}^{23}_{11}Na \rightarrow {}^{23}_{11}Na^{*} \rightarrow \gamma + {}^{23}_{11}Na + \cdots \\ \alpha + {}^{36}_{18}Ar \rightarrow {}^{36}_{18}Ar^{*} \rightarrow \gamma + {}^{36}_{18}Ar + \cdots \end{cases} \qquad (2)$$

The presented total cross-section in Fig.1–Fig.9 shows the full picture of the induced γ-ray spectra selected from [8]. In the next section, we will present the cross sections for neutron spalling (or evaporation) reactions as a result of the noted collisions of protons and α-particles. The total effect of all the presented channels leads to the formation of the background γ-spectrum necessary for quantitative analysis. Against this background, in 2017, the detectors registered the positron emission line of positron-electron annihilation. In this case, we have the necessary testing of the proton-excess nuclear formation.

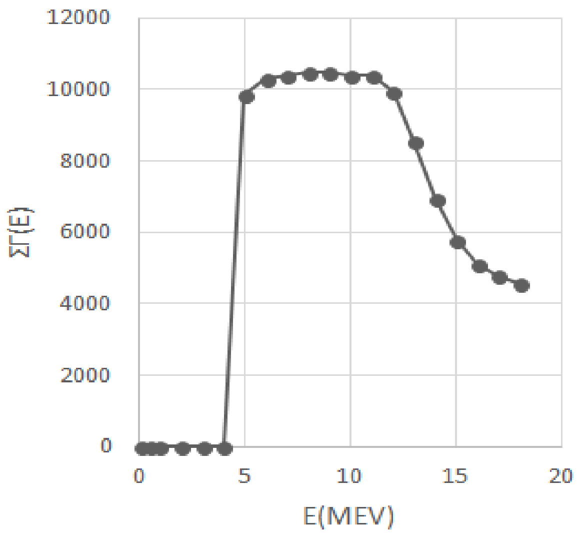

Fig.5 ΣΓ(E) of γ-emission $\alpha + {}^{4}_{2}He$-->γ +...

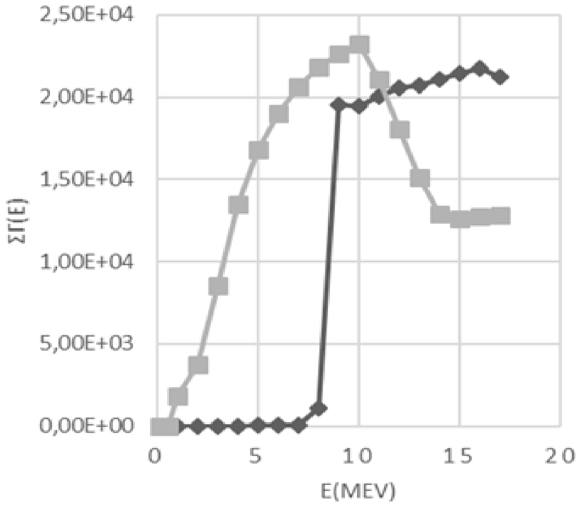

Fig.6 Cross section ΣΓ(E) of γ-emission ♦ - $\alpha + {}^{12}_{6}C$-->γ +..., ■ - $\alpha + {}^{13}_{6}C$-->γ +...

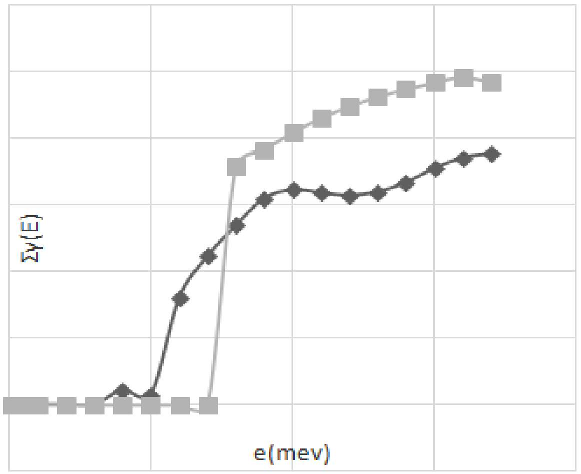

Fig.7 Cross section ΣΓ(E) of γ-emission. ♦ - $\alpha + {}^{14}_{7}N$-->γ +..., ■ - $\alpha + {}^{16}_{7}O$-->γ +...

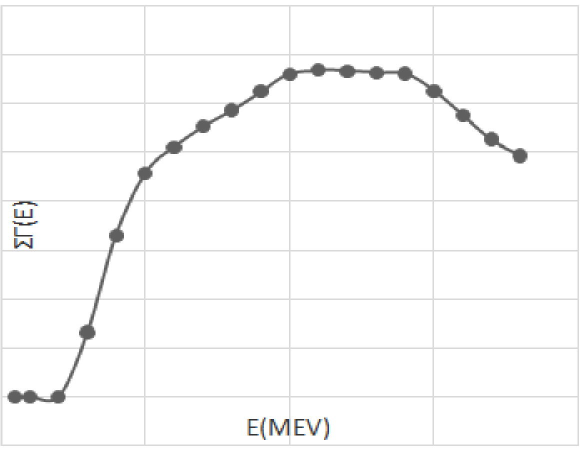

Fig.8 Cross section ΣΓ(E) of γ-emission $\alpha + {}^{23}_{11}Na$-->γ +...,

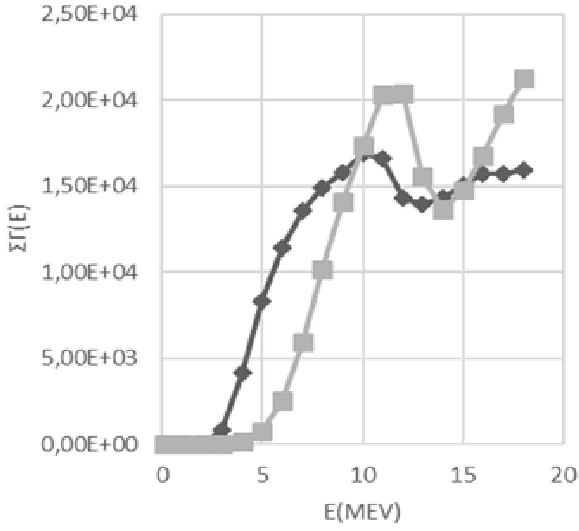

Fig.9 Cross section ΣΓ(E) of γ-emission♦ - $p + {}^{36}_{18}Ar$-->γ +..., ■ - $\alpha + {}^{36}_{18}Ar$-->γ +...

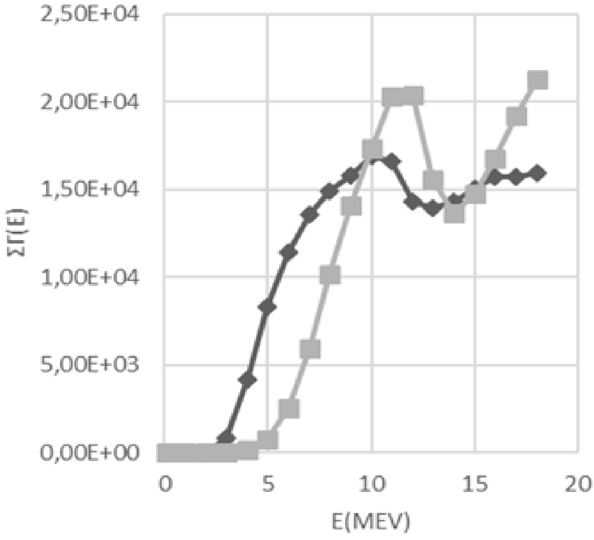

Fig.10 Cross section ΣΓ(E) of n-emissionα+${}^{14}_{7}N$-->α+n +${}^{13}_{7}N$..., ${}^{13}_{7}N \rightarrow {}^{13}_{7}C + e^{+}$

2.3 Positron Formation in Lighting. One of the protons and α-particle impact channels of nuclear transformations is the formation of proton excess atoms. Mainly these nuclei decay with positron emission.

The reaction link α+$^{14}_{7}N$-->α+n +$^{13}_{7}N$…,$^{13}_{7}N \rightarrow {}^{13}_{7}C + e^{+}$ shows only the trace nature of the production of positrons. The half-life of $^{13}_{7}N$ is 10 minutes. The threshold energies of other nuclear reactions of similar isotopes lie far from the energies of the electric field of lightning, located in the range of 0.1-10.0 MeV in Fig.1-Fig.9. The very fact of the establishment of electron and positron annihilation lines already allows us to establish that protons and α-particles should have a lower energy threshold of 7-10 MeV. The evolutionary structure of the γ spectrum is as follows. The time-life of the γ-flayer is 200 μs. At this time luminosity of the annihilation 0.511MeV line increased during the half-lifetime (10 min). After this time observe his degradation. To ensure the completeness of information, the time intervals for retrieval of information should be 10^5 records in 1 sec. from each layer of the detector.

3. Detection of the lighting flash. Physical aspects. For calibration of the fast γ-ray spectrograph, it is necessary to carry out its preliminary calibration in various operating modes. The previous sections present the emission characteristics of various elements from Table 1. The main glow of lightning is occurring in the short-wavelength part of the spectrum. In its upper part, we expect an intense spectrum from ultraviolet to X-ray spectrum. In this case, the choice of the perovskite CsPbBr3 crystal design in the spectrograph detector is important [4,5]. At the initial time of interaction, all radiation from lighting spectra interacts with near surface layers. High energy quanta reach the deeper layers. In the end, γ-quanta of the highest energies reach the last layers. The physical aspects of quantum detection in many-layer crystal structures are important for the identification and selection of impulses accompanying the noise and the useful signal. The mean lighting spectral structure consists of all kinds of quanta. From radio waves to γ-rays. Let having an n-layer detector with an n-semiconductor layer and n+1 isolator surfaces. As can be seen from Fig. 9, it can be assumed that quanta of ever higher energies are absorbed in each subsequent layer. Accordingly, the lowest layer absorbs the last quanta that have reached it.

The hard radiation intensity $I_{\lambda}(\ x\ )$ on the deep x with wavelength λ under surface are considered from formula.

$$I_{\lambda}(x) = I_{o}e^{-kx} \tag{3}$$

where k = σn, n is the concertation of the atoms in the detector, σ is the cross-section of three kinds of interaction atomic photo-, Compton- effect, and creation near heavy atom of the electron-positron pairs. In presented spectral intervals the creation of the electron-positron pairs is unlikely[6,7]. But Compton scattering $\sigma_c$and photo effect cross sections σ_{ph} dominated in γ-ray interaction with heavy element semiconductor CsPbBr3 and well-studied. To calculate the necessary technological parameters and the geometric structure of this semiconductor, it is necessary to calculate the path lengths of quanta until they are completely absorbed due to the action of the scattering and absorption processes noted above.

$$\sigma_{ph} = \frac{5}{4} \cdot 1{,}09 \cdot 10^{-16} Z^5 \left(\frac{13{,}61}{E_\gamma(eV)}\right)^{\frac{7}{2}} cm^2 \quad when \frac{E_\gamma}{mc^2} \ll 1 \qquad (4a)$$

$$\sigma_{ph} = \frac{5}{4} \cdot 1{,}34 \cdot 10^{-33} Z^5 \left(\frac{1}{E_\gamma(MeV)}\right) cm^2 \quad when \frac{E_\gamma}{mc^2} \gg 1 \qquad (4b)$$

$$\sigma_C = 2\pi r_e^2 \left\{ \frac{1+\varepsilon}{\varepsilon^2} \left[\frac{2(1+\varepsilon)}{1+2\varepsilon} - \frac{1}{\varepsilon} \ln(1+2\varepsilon) \right] + \frac{1}{2\varepsilon} \ln(1+2\varepsilon) - \frac{1+3\varepsilon}{(1+2\varepsilon)^2} \right\} \qquad (4c)$$

Where $r_e = e^2/(m_e c^2) = 2.8 \cdot 10^{-13}$ см, $\varepsilon = E_\gamma/(m_e c^2)$. In [4,5] presented semiempirical testing of absorption capabilities $k = (\sigma_{ph} + \sigma_c + \sigma_{pair})n$ in $CsPbBr_3$ crystal. If absorption length is $x = 1/k$ then $I_\lambda(x)/I_o = e^1$. In energy interval $0.001 MeV \le E_\gamma \le 10\ MeV$ the $10^{-3} cm \le x \le 10^3 cm$.

Thus, for γ-quants formed the annihilation line with $E_\gamma \approx 0.511 MeV$ the detector thickness x is 0.3-2 cm.

Fluorescence in detectors. The K-L-M-N-O energetic structures of the Br, Cs, and Pb atoms a presented in textbooks about atomic spectroscopy. The soft γ-ray mainly interacts with the K-shell and forms a bulge. After that atom is in a highly excited state. To remove the excitation, cascades of electronic transitions of the form are most probable. Mainly this is 3d-->2p-->1s transition. The 5f – level of Cs and Pb atoms is not occupied. Along with this, the selection rules allow a less probable direct electronic transition 3d-->1s. The selection rules for the atoms of interest to us do not forbid vertical transitions either. Despite their low probability, we present them in Table 2. The selection rules for the atoms of interest to us do not forbid horizontal transitions either 2p-2s, 3d-3p-3s, or 4d-4p-4s Despite their low probability, we present them in Table 2. The semiconductor will spend the remaining energy on injecting electrons from the band gap into the conduction band.

In recent works and reviews on CsPbBr3 perovskite [4,5], it was reported that the accuracy of determining the energies in the contours of the spectral lines is already several percent or 7–10 keV. In this case, it is possible to average the results of detailed calculations of the energy structure of atoms for the corresponding shells homogeneous in quantum numbers. In Br, Cs, and Pb atoms, only the L and M subshells participate in cascade transitions to K or another vacancy. Averaging the energy within each subshell makes it possible to obtain the weighted average energy of the quantum transition belonging to the vertical cascade. When calculating less probable horizontal transitions, we will adhere to the results of calculations by the Hartry-Fock-Dirac methods. The radiative response in the CsPbBr3 semiconductor can lead to an outflow of part of the energy from its surface in the form of X-ray, less often hard ultraviolet radiation. The considered fluorescence is an important possibility for recording and subsequent diagnostics of emitters of γ-spectra. Table 2 presents the results of calculations of the average energy structure of electronic levels for Br, Cs, and Br.

The cascades of L-K, M-L, and M-K transitions induced by a single γ-quantum lead to the emission of secondary quanta, which have much shorter path lengths. On the radiation absorption spectrograms presented in [4, Fig.2, C] one can see the peaks

Table 2. The mean energetic structure of the internal electron's subshells K, L, in Br, Cs, and Pb. E in eV

Element\Subshell	K(ineV)	L	M	L-K	M-L	M-K
Br (a. n. 35)	13481	1646	160	11835	1486	13321
Cs (a. n. 55)	35987	5364	954	30623	4410	35033
Pb(a. n. 82)	86011	14705	3054	71306	11651	82957

preceding the corresponding formation of K-vacancies and further, close in energy L-K transitions. An increase in the accuracy of recording γ-spectra will make it possible to judge the formation of primary vacancies at higher levels as well. Technologies for growing perovskite, including CsPbBr3, are noticeably improved. Recently, their thickness is approaching 1-2 cm. According to [4, Fig2. C] for energies of the order of 0.511 MeV, this perovskite layer absorbs the flux of γ-quanta by a factor of e. On these scales, a γ-quantum once creates a vacancy on Pb, Cs, and Br atoms with probabilities of 80%, 35%, and 10%. The rest of the energy is transferred to two or one K-electrons and is effectively transferred to the crystal structure of the semiconductor at lengths of 1-2 mm. X-ray L-K and M-L quanta are partially absorbed by the crystal body depending on its size but mostly leave the detector.

Current pulse formation. Having considered the elementary processes of absorption of γ-quanta and induction of X-ray fluorescence, it is possible to estimate the number of electrons passing from the valence band to the conduction band. The energy of the creation of electron-hole pairs in a semiconductor is 5,3 eV. Then the pulse from unit γ-quants with energy 0,511 MeV. The non-amplified current pulse cascades presented in formulae (4a) - (4c) is$I_p = \Delta q/\Delta\tau$, where $\Delta q \approx 1.54 \cdot 10^{-14} C$ and $\Delta\tau \approx 10^{-3}$s. Then $I_p \approx 15.4 \cdot 10^{-12} A$ or $15.4\, pA$. At the same time, the dark current is near 5 pA. The main technological experiments were taken atmeasurements with an external potential difference of Δφ = 500V. Taking into account dissipative losses in this semiconductor, it seems possible to amplify a unit current amplitude up to 50-60 μA. At the same time, the noise amplification factor is smaller and can reach up to 10-15 μA under normal conditions. At present, the main noise suppression efforts are primarily aimed at optimizing their manufacture. The absence of the need to lower the detector temperature leads to a significant reduction in the cost of the final product - the γ-spectrometer.

The γ-radiation from lighting. The probability of illumination of hard radiation during the discharge in the thunder lightning may be defined bythe interaction between one proton or α-particle with atmospheric gas. In internal upper parts of the currents tube one the characteristic length L_{ch} of the formation of one nucleus in channel α+$^{14}_{7}N$-->α+n +$^{13}_{7}N$...,$^{13}_{7}N \to {}^{13}_{7}C + e^{+}$… and its subsequent decay with the emission of a positron $e^{+}$is $L_{ch} = 1/n\sigma \approx 10^{3} cm$.The mean free path of positrons has a close value. For the upper limit of the number of α-particles in the current, one can set the concentration of helium atoms. The statistics of the location of the positive charge in the cloud, and the minus charge on the Earth's surface shows that the flow of protons and α-particles is immediately formed in the lightning head and this area is the main source of γ-radiation. The temperature surge inside the lightning, the maximum value of which is 10^5 K, cannot cause the complete full ionization of He. Impact electron ionization can be the main ionization mechanism. Protons and α-particles experience large ionization losses at the beginning of their movement. However, after a few tens of meters, with increasing speed, their specific value decreases. Taking into account the relative concentrations of chemical elements in the Earth's atmosphere, we can estimate the concentrations of atoms participating in the considered channels of nuclear transformations from the next estimation:

$$n_{N_2} \approx 3.27 \cdot 10^{22} cm^{-3};\ n_{He} \approx 5.59 \cdot 10^{18} cm^{-3} \qquad (5)$$

Taking into account L_{ch} and threshold values of the cross sections shown in Fig.10 the proportion of protons and α-particles reaching the threshold values of reactions (Fig. 10) is small. We estimate 0.01% of the numerical number n_{He} achieve favorable conditions for the formation of a radioactive isotope $^{13}_{7}N$. In this case, we get 10-50 γ-quanta per cm^2 of the detector surface.

Discussion. The accidental discovery of γ-flash during strong lightning discharges allows us to assert that nuclear transformations occur in such physical systems. The interaction of relativistic electrons with atoms and ions also generates bremsstrahlung, but it belongs to the UV range of the spectrum. Against the background of increasing the accuracy of γ-radiation detectors (1%-2%), the resolution of spectral line profiles approaches 1 KeV. This means that the channels of nuclear transformations can be identified. During the course of nuclear transformations caused by lightning, the isotope $^{13}_{6}C$ is formed from reaction α+$^{14}_{7}N$ →α+n +$^{13}_{7}N$...,$^{13}_{7}N \to {}^{13}_{7}C + e^{+}$.... In the present work, it is shown that its formation competes with the mechanism of action of cosmic rays to the upper layers of the Earth's atmosphere. In this case, positron annihilation is an additional diagnostic tool for studying the regimes of energy transfer in the plasma of a current discharge. The planned placement of the detectors in the mountainous area adjacent to the city of Smolyan, Bulgaria by one of the co-authors of this article (MD) will make it possible to bring the detector closer to the source of the γ-burst formation. The binary detectors described in the article [7] can be especially informative. In this case, we obtain simultaneously γ- and optical spectra within the same instrumental function. We would like to draw attention to the fact that the proposed method is highly effective in monitoring other fast-moving phenomena.

Conclusion. In the present work, a new method for detecting high-resolution spectra both in time and in the amplitude of the processes under study was presented. In this sense, the choice of objects of the study was that the time frames of the processes fit into the intervals from 10^{-5}s - 1 s, and the energy intervals of the spectrum reached 10 MeV. To date, the method of positron γ-spectroscopy developed by us has been applied to astrophysical objects that will have thermonuclear explosions on the surface of compact relativistic objects called White Dwarfs (WD), which are members of close binary systems. Irregular outbursts at such polar objects occur several times a year. Firstly, this method tested for supernovae blast envelopes [1, 2, 9].

Since 2017, thanks to more sensitive γ-sensors, γ-radiation flash from lightning have been registered near Japanese atomic stations. Thunderclouds are aerosols, which, in addition to various phases of water, include impurity dust particles, smoke, and, in some cases, sea and ocean salt. Taking into account the risks in the study of lightning, we believe that the remote combined γ- and optic spectrographs allow us to preserve the completeness and unambiguity of the physical parameters of the object of study. For the two types of objects indicated, the characteristic times of the processes of production of γ-quanta are usually much shorter than those of relaxation processes in optics.

We identified of themain physical processes that describe the upper part of the lightning, where current discharge can form streams of ionized hydrogen and helium due to the impact of electron ionization. Really only nuclear transportation α+$^{14}_{7}N$ →α+n +$^{13}_{7}N$...,$^{13}_{7}N \to {}^{13}_{7}C + e^{+}$.... and him cross section is main affective source of positron and annihilation quanta $\left(E_{\gamma} = 511\,\mathrm{MeV}\right)$. We have found that with a potential difference of 10^{8} V, protons and α-particles reach an energy of 8-10 MeV in the lightning head, their energy is sufficient to initiate nuclear transformation or create induce γ-ray quanta. In details in Fig.1–Fig. 4 for proton impact, and in Fig. 5 – Fig.9 for α-particle impact.

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Д.М. Дойков, М.Д. Дойков

Позитронна спектроскопія γ-спалахів в атмосфері землі.

АНОТАЦІЯ

Відкриття нової генерації напівпровідників на базі перовскітів, тобто $CsPbBr_3$, відкрило нові можливості для їх впровадження в техніку вимірювань γ-спектрів. У статті проведено моделювання позитронних та індукованих зіткненнями протонів та α-частинок з атомами атмосфері Землі γ-спектрів протягом дії блискавок. Враховуючи інтервали часу і енергії в яких діють вивченні явища в аерозолях Землі розглянуто структуру таких γ-спектрів. Запропоновано вивчати блискавичну плазму у інтервалах часу від 10^{-5}с до 1 с. Інтервали енергії від (0.01 – 10)МеВ. У голові блискавки різність потенціалів досягає 10^{8}В, а розрідженість збільшує довжину вільного пробігу у три разі у порівнянні с рівнем моря. Тому енергетичного ресурсу електричного поля блискавки достатньо для прискорення електронів, протонів и α-частинок до 6-8 МеВ. Іонізаційні втрати і втрати від пружних зіткнень сорту частинок залежать від кожного каналу їх взаємодій з атомами атмосфері Землі. Тобто енергії частинок лімітовані з боку верхньої границі. Після вибору каналів було проведено відбір та розрахунок залежності повного перерізу зіткнень для відібраного каналу реакцій зіткнень і потім ядерних перетворень. Рис.1 – Рис.4 з участю протонів, Рис.5–Рис.9 з участю α-частинок. Розглянуто формування радіоактивних ізотопів з ексцесом протонів, розпад яких доводить до формування позитронів і меншого за номером стабільного ізотопу. Було отримано, що найбільш можливим ланцюгом ядерних перетворень е реакція «випарювання» нейтрону: α+${}^{14}_{7}N$ → α+n +${}^{13}_{7}N$...,${}^{13}_{7}N \rightarrow {}^{13}_{7}C + e^{+}$. Зроблено та показано переріз реакції Рис.10. Нижня енергетична границя реакції лімітована значеннями у 6 МеВ. Зроблено висновок про кінетичну енергію α-частинок у цьому каналі ядерних перетворень. Розрахунок продуктивності каналу дає 20-40 γ-квантів з анігіляції позитронів з електронами (E_{γ}=0.511 МеВ). Потік індукованих γ-квантів складає (100-200) на см-2 детектору у момент токового вибуху блискавки. Проведено розрахунок струмових імпульсів від кожного з квантів кристалом детектора. Мінімальній імпульс складає 15 nА. Темнавий струм (5-10) nА. Тому потік γ-квантів вид блискавок може давати до 50 нА. Для оптимізації роботи детектора і підвищення чутливості використовується різниця потенціалів 500 В. Треба зазначити, що для зменшення темнового струму перовскітів охолодження детектору практично не потрібно і дає значний економічний ефект. Одночасно з цим корисний імпульс зростає до мікроампер і легко обробляється доступним для придбання обладнанням.

Ключові слова: *іоносферна плазма, плазма з КДФ в струмових трубках, локальне електричне поле атмосфери, γ-спалахі.*