ON POSSIBILITY OF SHORT-LIVING POSITRON-EMITTING NUCLIDES PRODUCTION USING ELECTRON ACCELERATOR FOR MEDICAL DIAGNOSTICS

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Comparison is made of technologies of radiopharmaceuticals (RPC) production that are labeled with positron-emitting nuclides using a cyclotron and an electron accelerator (EA). It is shown that specific activities of RPC produced on EA are sufficient for the γ-camera and PET diagnostics.

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1. INTRODUCTION

Short-living positron-emitting nuclides ^{11}C, ^{13}N, ^{15}O and ^{18}F are labels for pharmaceuticals used for diagnostics on a positron-emitting tomograph (PET). Traditionally they are produced on a cyclotron by exposing the targets to accelerated protons ($18\,MeV$) or deuterons ($9\,MeV$) [1]. The target thickness does not exceed 1 cm with a high specific activity. After irradiation the target is transported to the radiochemical laboratory where the RPC is synthesized. The RPC having been produced is injected to the patient and then scanning is performed on the PET tomograph. The activity injected to the patient amounts $3...5\,mK$ ($1.8 \times 10^8\,Bk$).

The RPC quality is monitored and must satisfy such demands as sterility, apirogeneity, chemical and radiochemical purities. The cost of the targets used for production of the above mentioned nuclides is not high. The exception is the target for ^{18}F production that is formed in the $^{18}O(p,n)^{18}F$ reaction. For this the water is used enriched with the ^{18}O isotope (0.2%) in the natural mixture, its content should amount 70...90%. The cost of the diagnostics with 18F is determined by the cost of such water which is produced in Ukraine as well.

The PET diagnostics allows one to find the localization and size of new growths at the stage where other known methods cannot reveal this yet. The above mentioned nuclides emit positrons with different energies. As a result of positron interaction with the medium electrons, the annigilation of these particles happens with formation of two $511\,keV$ γ-quantums with the 180° angle of scattering which are recorded by the counters forming the ring of the PET scanner. The detecting system (a ring detector containing up to 1000 counters) records less than 2% of all irradiated γ-quantums. It is the low efficiency of g quantum registration that results in a high activity of RPC injected to patients.

2. THE POSSIBILITY OF USING AN ELECTRON ACCELERATOR

We consider the possibility of using an electron accelerator (linear one or microtron) for production of above-mentioned positron-emitting nuclides and manufacturing RPC on their basis. These nuclides can be produced on an electron accelerator supplied by the converter. The accelerated electrons generate γ-quantums (bremstralung) in the field of retarding target nucleus (converter). The bremstrahlung spectrum is continuous, and the maximum energy of γ-quantums is $(E_{max} - m_e c^2)$ where E_{max} is the maximum energy of electrons. Such γ-quantums can excite the (γ, n) reaction, its products being the nuclides necessary for diagnostics. As the neutron bonding energy in the nucleus amounts about $8\,MeV$ in average, the thresholds of these reactions are of the same value. The (γ, n) reaction cross-section is a maximum at the energy $15...17\,eV$ and drops to zero at $25...27\,eV$. Therefore, the maximum energy of the accelerated electrons should not exceed $30\,MeV$ not to excite the (γ, p), (γ, d), (γ, pn), $(\gamma, p\alpha)$ reactions that will result in formation of impurity nuclides. The cross-sections of these reactions amount tens mB and are substantially less than cross-sections on protons and deuterons. The divergence of the beam of γ-quantums in steradians is characterized by the Θ value which is equal to the electron rest energy $mc^2/electron$ maximum energy ratio. This quantity determines the target diameter irradiated by the γ-quantums. At least 95% of high-energy quantums must hit the target. The peculiarities of investigations on the beams of bremstrahlung γ-quantums are described in detail in [2], and data useful for exper-

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imentalists are in the monograph [3]. Photoneutron sources are described in the monograph [4]. The longitudinal size of the target is determined by the free path of γ-quantums, their slowing-down to the (γ, n) reaction threshold. As the γ-quantums loose their energy exponentially, the longitudinal size of the target, proceeding from the above mentioned data, is determined by the length of e-fold γ-quantum energy decrease. Therefore, the size of photo-nucleus target is 100...1000 times larger than that of cyclotron targets. This results in a low specific activity and large volumes of the liquid preparations. In this case, the intravenous injection is ruled out, and the peroral RFP delivery or the radioactive air inhalation are used. With this, the volume of the liquid is 100...200 times larger than that of the intervenous injection. The high penetrating ability of γ-quantums that generate short-living radionuclides allows one to use pharmaceutical preparations, such as the water for injections, the glucose solution and other medicinal forms. These forms can be used not only for radionuclide production but as RPS as well. In this case, all above mentioned RPS inspection demands are ensured. The activity produced in photonuclear reactions was estimated theoretically and experimentally by a number of authors [5-7]. The results of these works were compared with the data obtained in NSC KIPT within the frames of the STCU project [8]. Below Table is presented where the results obtained by different authors are compared.

Comparative data on isotopes production Isotope

Isotope	Specific activity, $Bk/g\mu A$ at $25\,MeV$		
	M.H. Mc Gregor [5]	G.L. Luts [6]	Our experiment*
^{11}C	$7.5 \cdot 10^6$	$0.8 \cdot 10^6$	$2.25 \cdot 10^6$
^{13}N	$3 \cdot 10^6$	$1.4 \cdot 10^6$	$3.36 \cdot 10^6$
^{15}O	$1.85 \cdot 10^6$	$1 \cdot 10^6$	$2.25 \cdot 10^6$
^{18}F	$1.85 \cdot 10^6$	$0.75 \cdot 10^6$	$1 \cdot 10^7$

$^*beforesaturation$

3. CONCLUSIONS

The data cited above show that the produced specific activities of isotopes coincide by the order of magnitude. The difference in the quantities at the factor 10^6 are explained by different experimental conditions - convertor thickness, irradiated sample size, its disposition in the bremstrahlung beam, distance between the output foil and the convertor and between the convertor and the irradiated sample. On electron accelerators regimes can be realized with currents amounting $20...50\,mA$. It is seen that activities produced at currents $100\,mA$ are sufficient for the PET diagnostics. The maximum counting rate for the γ-camera is limited by $5 \times 10^4\,pulses/s$. Such an activity amounts about 25% of that injected to the patient. Proceeding from the condition that only 25% of the activity participate in the diagnostics process and the injected radiation is extended over the 4π geometry, $2 \times 10^5\,Bk$ should be injected to the patient. As is seen in the Table, such an activity is produced on the electron accelerators. The processes of the peroral and respiratory activity injection are important because of a lower radiation loading on the medical staff. The γ-camera enables to make diagnostics of most of human organs. Therefore, it is reasonable to combine the PET-scanner and γ-camera.

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ВОЗМОЖНОСТЬ НАРАБОТКИ КОРОТКОЖИВУЩИХ ПОЗИТРОН-ИЗЛУЧАЮЩИХ НУКЛИДОВ НА ЭЛЕКТРОННОМ УСКОРИТЕЛЕ ДЛЯ МЕДИЦИНСКОЙ ДИАГНОСТИКИ

А.С. Задворный

Проведено сравнение технологий получения радиофармпрепаратов (РФП), меченных позитрон-излучающими нуклидами, получаемых на циклотроне и электронном ускорителе (ЭУ). Показано, что удельные активности РФП, полученные на ЭУ, достаточны для диагностики на γ-камере и для ПЭТ-исследований.

МОЖЛИВІСТЬ ВИРОБЛЕННЯ КОРОТКОЖИВУЧИХ ПОЗИТРОН-ВИПРОМІНЮЮЧИХ НУКЛІДІВ НА ЕЛЕКТРОННОМУ ПРИСКОРЮВАЧІ ДЛЯ МЕДИЧНОЇ ДІАГНОСТИКИ

А.С. Задворний

Проведено порівняння технологій отримання радіофармпрепаратів (РФП), мічених позитрон-випромінюючими нуклідами, які отримуються на циклотроні та електронному прискорювачі (ЕП). Показано, що питомі активності РФП, які отримані на ЕП, достатні для діагностики на γ-камері та для ПЕТ-досліджень.