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Gamma-Scanner for Control of Radiochemical Purity of Medical Isotopes

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Abstract—A gamma-scanner for measurement of radiochemical purity of medical isotopes was designed and tested. The measurements of radiochemical purity of sodium pertechnetate were conducted. The results of measurements confirmed the possibility of using the device for production of medical isotopes.

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1. INTRODUCTION

A method for producing ^{99}Mo/^{99m}Tc on the secondary gamma-ray beam from the linear electron accelerator LUE50 [1–3] of the Alikhanyan National Scientific Laboratory (ANSL) was developed. Experimental investigations of the specific activity of the output of ^{99}Mo/^{99m}Tc [4–6] were conducted, the possibility in principle of the production of the mentioned high purity medical isotope by means of an alternative non-reactor method was demonstrated.

The production of radioactive isotopes for health services requires the verification of their radioisotope and radiochemical purity. The conventional procedure for determination of radiochemical purity of a radioisotope is the method of ascending paper chromatography [7]. For control of radiochemical purity of isotopes, for instance, of ^{99m}Tc, many manufacturers use expensive complex gamma analyzers and scanners, only the smaller part of performance capabilities of which being availed of. The functions required for such an analysis may be perfectly realized by means of much simpler device.

The aim of the present work was to develop and create prototype a test-piece of such a device.

2. RADIOCHEMICAL PURITY AND THE MEASURING METHOD

The radiochemical purity is the percentage ratio of the activity of a radionuclide available in the preparation in the stable chemical form of the host material, to the general activity of the radionuclide in this preparation [8].

It is advisable to consider the parameter of radiochemical purity based on the example of radioactive isotope of technetium ^{99m}Tc, that is widely utilized in radiology at scanning by means of the method of one-photon computer tomography (OPCT) [9].

Irrespective of the method used for obtaining of this isotope, in the final product both the atomic technetium Tc, and the ions of sodium pertechnetate $NaTcO_4$ in the form of $[TcO_4]^-$ are available. The atomic technetium does not participate in the processes of metabolism of a living organism. The main component of the radiopharmpreparation on the basis of sodium pertechnetate are $[TcO_4]^-$ ions.

In the pharmacopoeia article (normative and technical document establishing the requirements to quality

of medicaments) for sodium pertechnetate, there is the requirement for percentage of atomic Tc that is should not exceed 5% of the total quantity of radioactive atoms.

2.1. Method of Paper Chromatography

In the paper chromatography substances differ by their relative position on the paper after passage by the solvent of some distance. The mixture solution to be separated is applied in small amount (10–20 mcl) at the reference point on the paper and dried. The resulting spot is called the starting point. The paper was then placed in a sealed chamber and one of its ends is immersed in a solvent that is a mobile phase. Under the action of capillary forces the solvent moves across the paper by solving and dragging along the components of the sample.

As prior to the start of motion the sample should be completely dissolved, the speed of components dissolution in the mobile phase is one of the factors determining the separation efficiency. After passage of a definite distance by the solvent, the list is removed and dried. Finally, the formed spots, that may be both visible and invisible, are detected and marked.

2.2. Measurements of Radiochemical Purity by Method of Paper Chromatography

Since both the atomic Tc, and the ionic $[TcO_4]^-$ have similar radioactivities, the ratio of Tc/$[TcO_4]^-$ activities may be measured using the method of thin layer (paper) chromatography. This aim in view, a microdroplet of pertechnetate solution is applied to the strip of chromatographic paper and then is developed using the column effluent – the methyl alcohol. The ionic component moves to the opposite edge of chromatographic strip, while the atomic one remains in place. After that the measurements of activity along the paper strip provide information on Tc/[TcO4] ratio.

3. SCANNER ARRANGEMENT AND ITS OPERATING PRINCIPLE

In ANSL for measurement of radiological purity of medical isotopes a gamma-scanner was elaborated, the block diagram of which is shown in Fig. 1. It consists of a control unit comprising electronic boards for pulse counter (*5*) and control of step motor (*7*), high-voltage power supply, discriminator (*4*), amplifier of input signal (*3*), mechanism with step motor (*8*) and a scintillation counter (*2*).

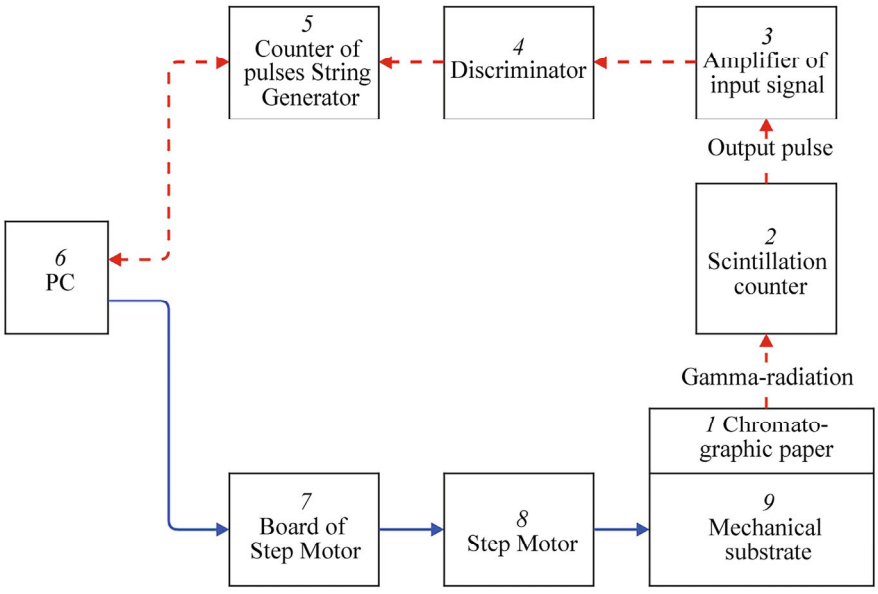

Fig. 1. Block diagram of gamma-scanner.

For performance of scanning procedure the treated chromatographic paper (*1*) is placed on the mechanical substrate (*9*). The scintillation counter (*2*) records the gamma radiation from the given position of chromatographic paper. The output pulse is supplied to the amplifier (*3*). The discriminator (*4*) converts analog pulses from the detector to the digital pulses fed to the pulse counter (*5*). The data are supplied to the PC (*6*) via RS232 interface. The number of pulses from the counter is summed by the software in the specified time period. On expiration of the specified time period the counting of pulses at the given position of chromatographic paper is stopped. A signal is sent by PC to the board of step motor (*7*). The step motor displaces the substrate with chromatographic paper to the next position. The counting cycle is repeated up to the last position of the chromatographic paper.

On completion of measurements the plot of activity distribution along the chromatographic paper is constructed and the ratio of Tc/$[TcO_4]^-$ is measured.

The overall view of the gamma-scanner is given in Figure 2.

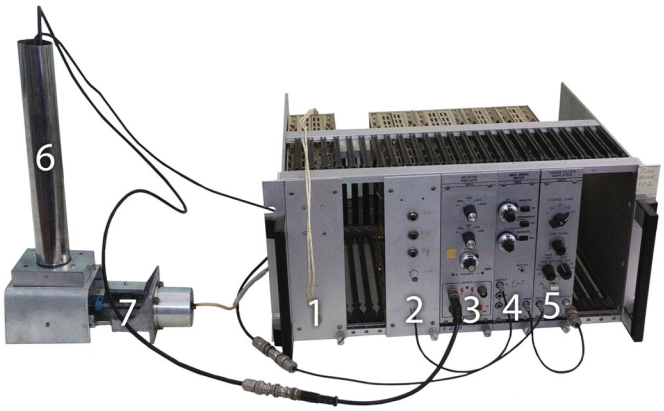

Fig. 2. Overall view of gamma-scanner: *1* – power supply, *2* – control unit, *3* – high-voltage power supply, *4* – discriminator, *5* – amplifier, *6* – scintillation counter, *7* – step motor with chromatographic paper substrate.

Scintillation counter consists of collimator with aperture of 5 mm in diameter, 35 mm high NaI(Tl) scintillation crystal of 22 mm in diameter, and PMT-87 photomultiplier.

The control unit consists of two modules: electronic board String Generator for processing and counting of input pulses from the scintillation counter, and Step Motor board for control of step motor. The scintillation counter is connected to high voltage power supply and its output pulse is amplified with the help of amplifier, passed through the discriminator and then supplied to String Generator board.

The computer communication is realized via RS232 port. The PIC microcontrollers installed in String Generator and Step Motor boards are programmed in assembler. The software of PC is written in Visual Basic 6 environment.

The software permits setting of the following scanning parameters: step length, the scanning time of each step, the number of steps. After scanning the data is stored in DAT-files format and processed in Microsoft Office Excel protocols.

4. MEASUREMENT OF THE RADIOCHEMICAL PURITY OF SODIUM PERTECHNETATE

For implementation of scanning, first the activity along the chromatographic paper is measured and the distribution activity of the corresponding spectral line of the isotope to be measured is plotted.

The purity of sodium pertechnetate with the following scanning parameters was examined: 3 mm scanning step, scanning time for each step is 300 s, number of steps is 13. The results of scanning are shown in Fig. 3.

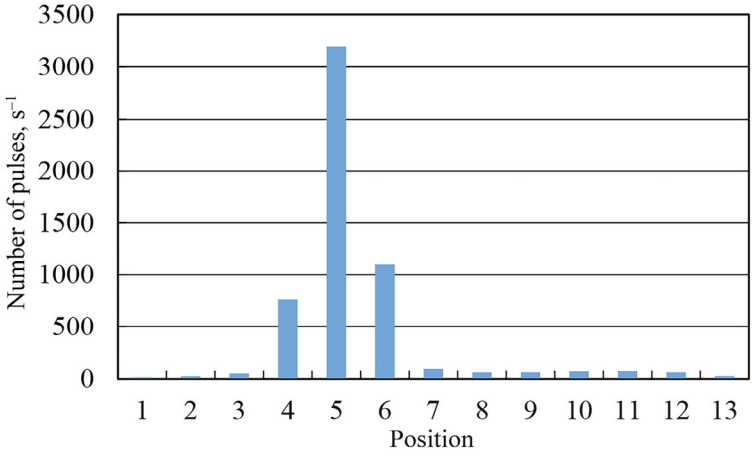

Fig. 3. Scanning results of sodium pertechnetate.

According to the scanning results, the ionic part of pertechnetate piled up in the 5-th position of chromatographic paper. The atomic component is relatively small in comparison with the ionic part and is observed in the 10-th and 11-th positions of chromatographic paper in the logarithmic scale.

5. CONCLUSIONS

A device for measurement of radiochemical purity of radioactive isotopes for health care purposes was elaborated, prepared and tested. The purity of radioactive isotopes was determined using the method of ascending thin layer paper chromatography. As a detector of gamma-radiation we used NaI(Tl) scintillation crystal. The device is a stand-alone equipment and ensures data output to computer. Control measurements of the radiochemical purity of ^{99m}Tc radioisotope demonstrated full compliance with requirements imposed by an appropriate pharmacopoeia article.

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