PRODUCTION OF RADIOACTIVE ISOTOPES BY PHOTONUCLEAR REACTIONS USING THE MT-25 MICROTRON

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The wide circulation of application of radioisotopes in nucle medicine, biochemical behavior of elements and environmental would b impossible without development of new methods for theirs of production.

The FLNR MT-25 microtron is an important installation for th production of wide variety of man-made radioactive isotopes.

On propose of academician of Flerov G.N. in 1980 year experimen were started at the microtron for producing of ^{123}I.

^{123}I

A method of producing a medical preparation of iodine-123 was developed. This isotope is very useful for medical diagnostics. The productio process is as follow:

^{123}I is obtained in photonuclear reaction ^{124}Xe (γ, n) ^{123}Xe →^{123}I. ($T_{1/2}$ =13.2 h) E_γ =159 keV. Enreached ^{124}Xe target is used. Productivity is 1 - 20 mCi [1].

Despite rather low productivity of this method the microtrons can compete with more expensive in operation the proton cyclotrons and to provide needs of separate clinics and regions. The complex installation for production ^{123}I consists of three main units - gas target of high pressure with system of diagnostic of a gamma-beam, chemical boxing with cell for concentration ^{12} and control of its quality.

^{77}Br

A similar method may be used for the production of ^{77}Br according the

^{78}Kr(γ, n)^{77}Kr (EC)→ ^{77}Br reaction on the enreached ^{78}Kr.

^{99m}Tc, $T_{1/2}$ =6,02 ч; IT (100 %); Eγ =140,5 кэВ (87,7 %).

The short lived isotope of ^{99m}Tc is applied as a radiotracer for studi of chemical behavior of technetium in the environment as well as in medicine for diagnostics of the urological and thyroid gland diseases.

As a result of study of the ^{100}Mo (γ, n) ^{99}Mo reaction some practical conclusions can be made. So the irradiation of 10 g ^{100}Mo (100 % of enrichment) by the electron current equal 25 μA with the 24 MeV bremsstrahlung for 100 hours produces
5.5 10^{10} Bq (55 GBq) of ^{99}Mo.

The irradiation of 10 g the natural molibdenum (^{100}Mo-9.63 %) in the above conditions forms 5.3 10^{9} Bq (5.3 GBq) of ^{99}Mo [2, 3].

^{95m}Tc, ($T_{1/2}$=60 d),

Analysis of ^{99}Tc in the environment and technological processing have been interested because of a long term radio ecological effect of ^{99}Tc due to its long half-life. One of the problems on ^{99}Tc analysis is a tracer since there is no stable isotopes in Tc. Development of ^{99}Tc determination by ICP-MS enables us to use ^{95m}Tc as a yield monitor. The radiochemical yield is evaluated by gamma spectrometry of ^{95m}Tc and ^{99}Tc is determined by mass spectrometry without any interference by ^{95m}Tc tracer added to the sample.

Production of $^{95m,g}Tc$ is possible in the Ru(γ, n)Ru → $^{95m,g}Tc$ reaction [3].

The irradiation of 1 g ^{96}Ru (100% enrichment) with 25 MeV bremsstrahlung (the electron current equal to 20 μA) for 100 hours produces 0.2 mCi ^{95m}Tc and 0.6 Ci ^{95}Tc.

^{143}Pm

The isotope can be produced by photonuclear reactions: $^{144}Sm(\gamma, p)$ ^{143}Pm, and $^{144}Sm(\gamma, n)$ ^{143}Sm →ES, β^- ($T_{1/2}$=8,8 m) → ^{143}Pm.

After irradiation of 1 mg of enriched (86,6%) ^{144}Sm with microtron 25 MeV γ-rays for a period of 5 hours, 10 kBk of activity could be obtained. The beam current was 10 μA. This method of producing ^{143}Pm is very effective, taking into account the low cost and the very high natural physical purity of its production using bremsstrahlung γ-quanta [4].

The radioisotope can be used as a standard for the calibration of γ-ray detectors (Eγ =742 keV) and also finds application in nuclear medicine for curing the metabolism of animals.

^{225}Ac

One of the most trends of the modern nuclear medicine is the application of new radioactive isotopes for development of diagnostic methods and treatment of the various diseases. From this point of view the production of ^{225}Ac ($T_{1/2}$ = 10,0 d, E_α = 6,9 MeV) represents a large interest,

especially for the tumor's metastases radiotherapy. It may be used both therapeutic agent [5] and a source for short-lived ^{213}Bi production that is also of interest for leucaemia therapy.

The ^{226}Ra(γ, n) reaction is considered as one of perspective methods for ^{225}Ac production. It is necessary especially to note, that at an irradiation ^{226}Ra of γ-quanta there are no channels of reactions resulting to the formation of ^{227}Ra ($T_{1/2}$ = 42,2 min) and ^{227}AC ($T_{1/2}$ = 21,77 y), i.e. the isotopic purity of ^{225}Ac preparations will be determined only by radiochemical purity of the initial ^{226}Ra. From experimental data follows[6]: 1. The ^{225}Ac yield has been estimated as 550 Bq/μA·h·mg of ^{226}Ra.

2. The irradiation of 10 mg (1 g) of ^{226}Ra for 100 hours with average electron beam current ~20 μA by the MT-25 will allow to produce about 0.3 mCi (25 mCi) of ^{225}Ac.

3. The use of linear electron accelerator with electron beam current up to 500 μA would provide production of the same quantities of ^{225}Ac for 4-5 hours.

4. It is advantageous to repeat the ^{225}Ac recovery procedure several times for its more full extraction.

^{237}U

Due to its nuclear-physical characteristics ($T_{1/2}$ = 6.75 d; E_γ = 208 keV (21.7%)), ^{237}U is the best radiotracer for research on the behaviour of U isotopes in various chemical and biological systems. However as there are no convenient reactions for its production, this isotope does not find practical use.

The possibilities for production of ^{237}U in the ^{238}U(γ, n) reaction on the compact electron accelerator MT-25, using a recoil atoms collection, were examined.

The developed method allows producing ^{237}U on the MT – 25 microtron with purification from ^{238}U in 100 – 1000 times directly during irradiation without following masseparation.

^{236}Pu

One of the best-suited radiotracers permitting the determination of the isotopic ratio $^{239,240}Pu/^{238}Pu$, which enables identification of the source of contamination of the environment (nuclear tests, nuclear plant accidents, etc.) is ^{236}Pu.

^{236}Pu must meet stringent purity requirements. In particular, the concentrations of ^{238}Pu and $^{239,240}Pu$ should not exceed (Bq/Bq) of 10^{-3}-10^{-4} and 10^{-6}-10^{-7}, respectively. The existing methods of the ^{236}Pu production when satisfy these requirements are of low efficiency and expensive due to the need for an additional purification followed by mass separation procedures.

Expenditures on the production of ^{236}Pu in the reaction ^{237}Np (γ,n) are 10 times lower if comparing with reactions $^{235}U(\alpha,3n)$ (with the following mass separation) and $^{235}U(d,n)$. It allows us to consider that the reaction ^{237}Np (γ,n) is the most optimal one for producing ^{236}Pu with isotopic purity of 10^{-6}-10^{-7} Bq/Bq [7].

The possibilities of producing of radionuclides on the MT-25 microtron are listed in the Table. It contains the data referring to the production mode, estimates of expected yields.

Table. The production of radionuclides using of the MT-25 microtron

Nuclide	Nuclear reaction	Preparation procedure	Yield, Bq/μA·h
^{77}Br	$^{78}Kr(\gamma, n)\,^{77}Kr \rightarrow {}^{77}Br$	Chemical	10^6/g ^{78}Kr
$^{99}Mo \rightarrow {}^{99m}Tc$	$^{100}Mo(\gamma, n)\,^{99}Mo \rightarrow {}^{99m}Tc$		$2.2\cdot10^3$/mg ^{100}Mo
^{95m}Tc	$^{96}Ru(\gamma, n)\,^{95}Ru \rightarrow {}^{95m}Tc$		$3.8\cdot10^3$/mg ^{96}Ru
^{95g}Tc			$1.4\cdot10^7$/mg ^{96}Ru
$^{124}Xe \rightarrow {}^{123}I$	$^{124}Xe(\gamma, n)\,^{124}Xe \rightarrow {}^{123}I$		$1{,}5\cdot10^6$ / g ^{124}Xe
$^{144}Sm \rightarrow {}^{143}Pm$	$^{144}Sm(\gamma, n)\,^{143}Sm \rightarrow {}^{143}Pm$		$2\cdot10^4$/mg $^{144}Sm^{87\%}$
$^{225}Ac \rightarrow {}^{213}Bi$	$^{226}Ra(\gamma, n)\,^{225}Ra \rightarrow {}^{225}Ac$		$5{,}5\cdot10^2$/mg ^{226}Ra
^{237}U	$^{238}U(\gamma, n)\,^{237}U$	Recoil	10^3 /mg ^{238}U
^{236}Pu	$^{237}Np(\gamma, n)\,^{236}Np \rightarrow {}^{236}Pu$	Chemical	5/mg ^{237}Np

The data presented in the Table demonstrate that a large-scale production of may be organized on the microtron.

CONCLUSION

1. ^{99m}Tc The irradiation of 10 g ^{100}Mo (100% enrichment) with 25 M bremsstrahlung (the electron current equal to 20 μA) for 100 hours produ $4.4 \cdot 10^{10}$ Bq (44 GBq) of ^{99}Mo.

The irradiation of 10 g natural molybdenum (^{100}Mo-9.63 %) in the abo conditions forms $4.2\ 10^{9}$ Bq (4.2 GBq) of ^{99}Mo, that corresponds operating characteristics of industrial generators.

The obtained results are shown that it is possible to prepare ^{99m}Tc(^{99}M generators using the MT-25 microtron.

2. ^{95m,g}Tc . The irradiation of 1 g ^{96}Ru (100% enrichment) with 25 M bremsstrahlung (the electron current equal to 20 μA) for 100 hours produc $7.4 \cdot 10^{9}$ Bq ^{95m}Tc and $8 \cdot 10^{9}$ Bq ^{95}Tc.

3. ^{225}Ac. The irradiation of 1 g ^{226}Ra with 25 MeV bremsstrahlung (t electron current equal to 20 μA) for 100 hours produces ~ 10^{9} Bq ^{225}Ac.

4. ^{237}U. The irradiation of 10 mg ^{238}U with 25 MeV bremsstrahlung (t electron current equal to 20 μA) for 10 hours produces ~ 10^{6} Bq ^{237}U.