PROJECT OF THE RADIOISOTOPE FACILITY RIC-80 (RADIOACTIVE ISOTOPES AT CYCLOTRON C-80) IN PNPI

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INTRODUCTION

It is well known that the main sources for production of the radioactive nuclides are thermal neutrons reactors and accelerators of charged particles. Since in the last years new reactors were not constructed (in Russia the only reactor which construction has been finished in 2011 was the PIK reactor at PNPI in Gatchina) on the front place go the accelerators of the charged particles - cyclotrons, as the most safe and reliable technological installations. The list of cyclotron radio nuclides is much longer and more varied, than ones got on reactors. Cyclotron radio nuclides can be used both for diagnostics and for therapy. As to cyclotrons used in Russia for radioisotope production, mostly they have the energy of bombarding particles lower than 30 MeV, therefore the variety of nuclides produced with these installations is limited. The cyclotron of NRC "Kurchatov institute" is at present time the only working cyclotron with the energy of external proton beams of 30 MeV. As a result only there the isotope ^{123}I can be produced with the high radionuclide purity from a xenon target.

At INR of RAS (Troitsk) the powerful linear accelerator is in operation - Moscow meson factory. At 160 MeV proton beam branch the laboratory, which has the installation for irradiations of targets was created for production of medical radio nuclides [1]. This installation is one of the largest in the world in respect of beam energy accumulated in production of radio nuclides and providing a possibility to produce practically the whole list of accelerator radio nuclides. The essential disadvantage of this method is that the usage of the accelerators of such kind is very expensive and the production cost of medical radio nuclides by that method is considerably higher than by means of cyclotron with the proton energy up to 80 MeV.

SCHEME OF THE DESIGNED INSTALLATION RIC-80 (RADIOACTIVE ISOTOPES ON CYCLOTRON C-80)

In PNPI NRC KI (Gatchina) the project of the radioisotope facility RIC-80 (Radioactive Isotopes at cyclotron C-80) is being developed [2]. In fig. 1 the layout of RIC-80 installation is presented. The proton beam energy at the target will be of 40-80 MeV and the intensity up to 200 μA. This cyclotron is intended for production of a wide spectrum of medical radio nuclides for diagnostics and therapy and also for a treatment of ophthalmologic diseases by irradiations of a malignant eye formation. The cyclotron is located in the right side of experimental hall (ground floor) of the PNPI synchrocyclotron.

The outgoing proton beam is directed down to the underground floor and traced in the horizontal direction. After that the beam can be directed to one of target stations: a) the isotope mass-separator target by the 37 degrees clockwise deflection from "zero" beam direction; b) the target station by "zero" deflection and c) the target station by the 34 degrees counterclockwise deflection. The mass-separator with its target as the first target station will allow getting the separated isotopes of a high purity, which are implanted into a corresponding collector from which they can be easily extracted. Target stations will be equipped with special devices to download highly radioactive targets into protection containers to transport them safely to special storage places or to hot cells for the after-treatment and production of corresponding pharmaceutics.

ESTIMATED YIELDS OF RADIO NUCLIDES EXPECTED TO BE PRODUCED AT RIC-80 FACILITY

RIC-80 facility is unique being the largest in Russia cyclotron facility in respect of beam energy accumulated in production of radio nuclides and providing enough high energy of bombarding particles (proton energy of 80 MeV). It gives an opportunity to produce sources of a high activity within practically the whole list of radio nuclides produced at accelerators. In table 1 calculated activities of radio nuclides are shown, which are planned to be obtained at RIC-80 facility.

It is necessary to emphasize that the activities of radioisotopes are shown for production in the target. The actual activities extracted out of target material can be less because of incomplete extraction of produced radioisotopes.

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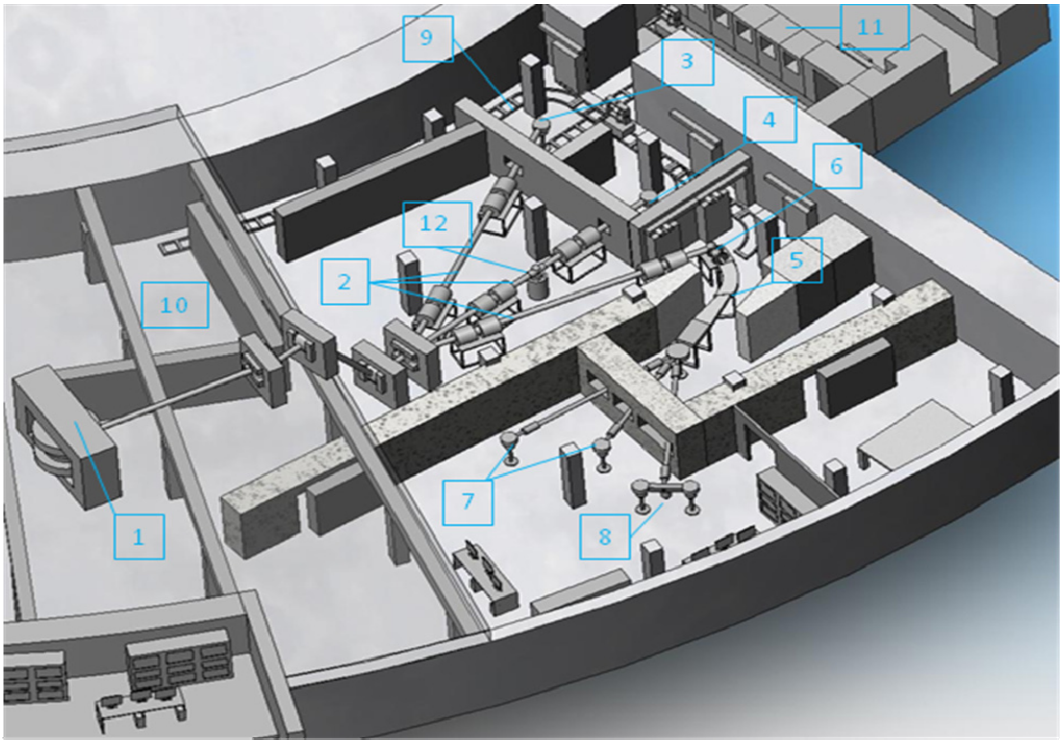

Figure 1: Layout of RIC-80 radio isotope complex. 1 – Cyclotron C-80, 2 – proton beam tubes, 3, 4 – target stations for radiochemical production of medical isotopes, 5 – mass-separator for production of medical isotopes of a high purity, 6 – target station of mass-separator, 7 – collecting stations for separated radio nuclides, 8 – detector stations for obtained radio nuclide purity measurement, 9 – transportation system for activated targets to special storage places or to hot cells, 10 –storage place for irradiated targets, 11 – hot cells, 12 – pneumatic rabbit station.

Table 1: Yields of some radionuclides planned to be obtained at RIC-80 facility with proton beam energy of 40-80 MeV and current of 100 µA.

Isotope	Half life	Target	Irradiation time interval (h)	Target Activity (Ci)
^{68}Ge	270.8 d	Ga	240	2
^{82}Sr	25.55 d	Rb	240	10
^{111}In	2.8 d	Cd	25	24.7
^{123}I	13.27 h	Te	5	10.4
^{124}I	4.17 d	Te	25	9.3
^{201}Tl	3.04 d	Tl	25	9.2
^{223}Ra	11.4 d	Th	240	7.3

For appropriate target developments the test experiments with target prototypes are performed presently at the synchrocyclotron in operation at PNPI for effective production of the listed nuclides.

Possibilities of the radionuclides production at RIC-80 installation are not exhausted by the list of isotopes provided in Table 1. The unique parameters of the C-80 cyclotron allow produce the broad nomenclature of radioisotopes, which are at present under discussion in corresponding publications as very perspective for diagnostics and therapy. The comparison of used for many years isotopes with new isotopes, which are under discussion and used in clinical tests brings us to a conclusion on trends to use more short-lived radionuclides to aim the diagnostics and therapy that significantly reduces the radiation rate for patients.

ON-LINE MASSES-SEPARATOR AT RIC-80 INSTALLATION TO OBTAIN MEDICAL ISOTOPE BEAMS OF THE HIGH PURITY

The production and study of radioactive isotopes by ISOL systems (Isotope Separator On-Line) is one of the fundamental directions of nuclear physics, as well as study of astrophysical processes in laboratory conditions. The main problem – the extraction and isotopic separation produced radio nuclides is under successful solution for 40 years already by means of ISOL installations at beams of different bombarding particles - protons, neutrons and heavy ions. Such on-line systems like ISOLDE (CERN,

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Switzerland) [3], ISAC (TRIUMF, Canada) [4], IRIS (PNPI, Gatchina) [5] under operation on-line at proton beams, allow to obtain at present more than 2000 separated isotopes of almost all elements of the Periodic system. Produced radioactive isotopes of half-life from several milliseconds to several thousand years are used in nuclear physics study, in solid state physics and in the radiation medicine.

On the base PNPI synchrocyclotron the single ISOL facility in Russia - IRIS (the Investigation of Radioactive Isotopes at Synchrocyclotron) is under operation, where radioactive isotopes of many elements are produced and investigated. At IRIS for more than thirty years different target-ion devices for production and studies of a very wide range of radioactive isotopes are developed and used. For the time of the facility operation more than 300 nuclei have been investigated and 17 of them have been identified for the first time. For the period since 2000 new target devices of high efficiency have been designed, which have been used for production of more than 50 radionuclides from areas of β^+, β^- и α decay. For nuclear physics studies radioactive isotopes of Mn, Fe, Co, Ni, Ga, Rh, Pd, Rb, Cd, In, Sn, Sb, Te, I, Cs, Tl, Pb, Bi, Po, At were produced using the targets made of a high density uranium mono carbide [6]. Liquid metal targets and a high temperature refractory metal targets have been used to produce radioisotopes of alkaline metals - Li, Rb, Cs and also isotopes of rare earth elements - Sm, Eu, Gd, Tm, Yb [7]. New developments and 35 years of experience in operation of IRIS installation will be used for the new ISOL system construction on-line with the beam of a high current C-80 cyclotron for production of intensive beams of medical radionuclides of a high purity.

The products formed inside a target material get out of target container kept at high temperature (1800-2200°C) by the diffusion-effusion process into an ion source, where the ionization occurs. Ions, going out of ionizer, are formed by the field of extraction electrode into a beam of ~ 2 x 10^{-2} radians divergence. Going through a focusing lens, ion beam is converted into a parallel and gains the energy of 30 keV. Later the beam of mono energetic ions enters the magnet-analyser, where the mass separation occurs. Beams of radioactive ions separated by masses enter the switchyard chamber and after that they go along vacuum ion guide tubes to the experimental hall, where they are implanted into corresponding collectors. Sources of radio nuclides obtained without any carrier and admixtures are measured in time of the accumulation process for the determination of their purity and activity rate by means of α, β and γ detectors installed close to collectors, where the radioactive ion beams are implanted. Coming from aforesaid one, the mass-separator method possesses the following values:

- allows to obtain very pure beams of isotopes of many elements;
- several separated radionuclides can be accumulated simultaneously;
- the implantation depth of tens Ǻ allows to use very fine organic substrates that can significantly simplifies the production process of pharmaceutics.
- the method of the radioactive ions implantation allows to obtain the unique generators of radioactive noble gases;
- the target can be used many times and does not require reconstruction;
- beside a number of relatively long-lived nuclides, mass- separator on-line at accelerator or reactor allows to obtain a lot of new "short-lived" radioactive isotopes ($T_{1/2}$ = from several minutes to several hours for diagnostics;
- process of the diagnostics can be realized "on-line" in medical laboratories, which are based on installations produced a big variety of short-lived mass-separated radioactive nuclides of a high purity.

The efficiency of the mass-separator method on the production of different nuclides varies in the range from some to ninety percents. So one of the main goals is the development of new highly efficient target - ion source devices specially suited for production of radionuclides with a high current medicine accelerators.

CONCLUSIONS

RIC-80 facility project will give an opportunity to use both the traditional radiochemistry method for the extraction of produced nuclides and the innovative mass-separator method, which will allow obtaining radionuclides of a high purity directly at the collector of the mass-separator, providing herewith an unique possibility to produce short-lived radioactive nuclides. By means of the advancement into a short half-life area the number of radionuclides in use (half-life from about some minutes to some hours) can be significantly extended. The corresponding studies of target materials and target – ion source device prototypes for RIC-80 facility were started in 2010 in the beam of PNPI synchrocyclotron.

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