PRODUCTION OF HIGH-PURITY ^{123}I ON IAE CYCLOTRON

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ABSTRACT

An automated target facility is described, which realizes the technology of ^{123}I production from enriched ^{124}Xe in proton-induced reactions.

A regular production of ^{123}I has been started. During a 4- to 5-h run of irradiation by a proton beam with the 32-MeV energy and 20-μA current, one obtains ~1 curie of high-purity ^{123}I.

1. INTRODUCTION

The importance of ^{123}I-labelled radiation pharmaceutical preparations for medical diagnostics is well-known. ^{123}I produced in indirect nuclear reactions, particularly, in irradiation of highly enriched (>99%) ^{124}Xe by the proton beam turns out to be most valuable for this purpose[1], since radionuclide contamination is minimal in this case and, therefore, the deadline for the radiation pharmaceuticals is maximal.

Until recently, there were no experimental data on the reaction cross sections

$^{124}Xe(p, 2n)^{123}Cs \rightarrow ^{123}Xe \rightarrow ^{123}I$

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The recently published ref. [2] presents only differential yields of ^{123}I, obtained in irradiation of 20 and 40%-enriched ^{124}Xe, which, probably, may be a source of errors in extrapolation to 100%-^{124}Xe, in particular, in the energy region higher than 30 MeV. Therefore, the IAE cyclotron was used to measure cross sections of these reactions and differential yields of ^{123}I on the 99.98% enriched ^{124}Xe [3] and the radionuclide yield was calculated for the case of a thick target (fig. 1).

The main criteria determining the choice of the proton energy for irradiation and values of the energy loss in the gas target were the integral yield of ^{123}I and the level of radionuclide impurities produced in this case. On the basis of experimental results obtained taking into account the possibility of radionuclide impurity production, the initial proton energy of 32 MeV was chosen. The gas target thickness corresponds to the proton energy loss in it of ~10 MeV.

2. TARGET FACILITY AND ^{123}I PRODUCTION TECHNOLOGY

To produce ^{123}I on the updated IAE cyclotron [4], a target facility with a "cryogenic" extraction of ^{123}I from the gas target was designed, as well as a complex of devices was constructed to ensure safety in performing this work (a ventilation system with filters for emergency absorption of ^{123}I, a decontamination centre, an additional biological shield, a manifold dosimetry system, a remote-control filling of liquid nitrogen, etc.). Unlike the technology, in which the ^{123}I produced is extracted from the gas target by washout of the sorbed radionuclide from the target walls by means of a weak solution of the NaOH alkali (as it is realized, e.g., in Karlsruhe [1]), in the employed "cryogenic" technology the irradiated xenon (comprising also the produced ^{123}Xe having $T_{1/2}$ = 2.1 h) was transferred, upon irradiation, into a "decay" vessel positioned in a Dewar vessel containing liquid nitrogen. In this vessel, the temperature of which is raised up to the room one upon the transfer, ^{123}Xe decays to ^{123}I and the latter is sorbed on the vessel walls. Upon cooling the irradiated gas in this vessel (the optimum cooling time is 6.6 h), ^{124}Xe is transferred into the initial vessel (once again by using the cryogenic method), while the "decay" vessel with ^{123}I sorbed on its internal walls is disengaged remotely, thrown off into a container and

transported to the radiochemical laboratory for labelling the radiation pharmaceuticals. The cryogenic technology is simpler and safer than that using the washout, while the efficiencies of the ^{123}I extraction from the target are close at irradiation times not more than 3 to 4 hours. Naturally, at longer times of irradiation there appear losses of ^{123}I produced on the gas target walls.

A layout of the target facility assembled in an isolated box is given in fig. 2. It comprises a gas target, a diagnostic block, a gas bench, cryogen and vacuum systems, water cooling, a foil helium cooling loop, hoists with liquid nitrogen Dewar vessels, remote control of all the systems.

The gas target (fig. 3) with the volume of $\sim$ 250 cm^3 is made of aluminium to decrease the residual radioactivity and has a form of a truncated cone 20 cm long with the inlet window diameter of 1.5 cm and the aperture angle of 6.5°, determined in experiments on multiple scattering of protons in xenon.

The initial gas pressure in the target amounts to 8 atm. The target has a water cooling jacket. The block of foil windows, consisting of an outlet window from the cyclotron ion conductor and the inlet one into the gas target (molybdenum of 50 μ), is cooled by a flow of gaseous He at a temperature of $\sim$20°C with the flow rate of 3 - 5 l/s. In the case of rupture of the foil window, the gas from the target could be collected in a cryogenic trap mounted in the helium cooling loop. If in so doing the intactness of the window from the cyclotron ion conductor is also broken, the gas will be stopped by a quick-operating gate and a fast vacuum slide valve positioned in the ion conductor (by the way, no such accidents have ever happened).

The gas bench realized on the basis of remotely controlled valves ensures the performance of the basic production operations on preparation and carrying out of irradiation and comprises a transportation gas storage vessel and the decay vessel made of stainless steel. Upon termination of the technological cycle, the decay vessel with ^{123}I is remotely thrown off into the transportation container mounted on a self-propelled chassis ensuring the putting down of the container cover and its transportation out of the experimental cabin.

The hoists with the Dewar vessels mounted on them are intended for the cryogenic transfer of the gas, with the use of liquid nitrogen as a cooling agent. The Dewar vessels are filled with liquid nitrogen remotely. Approximately 70 l of N_2 is consumed per cycle.

The remote-control and measurement system ensures the performance of different operations on the radionuclide production and checks all the technological parameters, namely: the proton beam current, the gas pressure, the vacuum in pumping, the temperatures of the target facility elements, the cooling water heating, the flow rate of cooling media, etc.

3. RESULTS

In 1988 the regular production of ^{123}I was begun with an average periodicity of once a fortnight.

The time of the target irradiation by the proton beam with the energy of 32 MeV and the current of $\sim$ 20 μA amounted to 4 h. During the irradiation, as a result of the gas heating by the proton beam, the ^{124}Xe pressure in the target increased from 8 to 15 atm. At the moment of transfer to the radiochemical laboratory, the decay vessel contained, on the average, $\sim$1 curie of ^{123}I, which was less than the calculated value from fig. 1. This may be explained by the presence of the so-called "thermal dip of concentration", which appears in the target due to the gas heating by the beam, as well as by losses of the radionuclide produced in the target in irradiation.

The experience gained during half a year of regular work has shown that the gas loss per irradiation run is $\sim$1%. The performed analyses have revealed an extremely low content of radionuclide impurities (^{121}Te, $^{123}Te \leq 10^{-4}$%, $^{125}I < 10^{-3}$%).

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REFERENCES

1) Bechtold, V., Fehsenfeld, P., and Schweickert, H., "Industrial Applications of the Karlsruhe Compact Cyclotron", in Proceedings of the 11th Conference on Cyclotrons, 1987, pp. 593 - 596.
2) Firovzbakht, M.L., Teng, R., Schlyer, D.J. and Wolf, A.P., "Production of High-Purity Iodine-123 from Xenon-124 of Energies Between 15 and 34 MeV", Radiochimica Acta, Vol. 41, 1 (1987).
3) Kurenkov, N.V., Malinin, A.B., Sebyakin, A.A., Venikov, N.I., "Excitation Functions of Proton-Induced Nuclear Reactions on ^{124}Xe: Production of ^{123}I", J. Radioanal. Nucl. Chem., Letters, Vol. 135, 39 (1989).
4) Venikov, N.I., Unezhev, V.N., Yudin, L.I., "Recent Modernization of IAE Cyclotron in Moscow", in Proceeding of the 11th Conference on Cyclotrons, 1987, pp. 84 - 87.

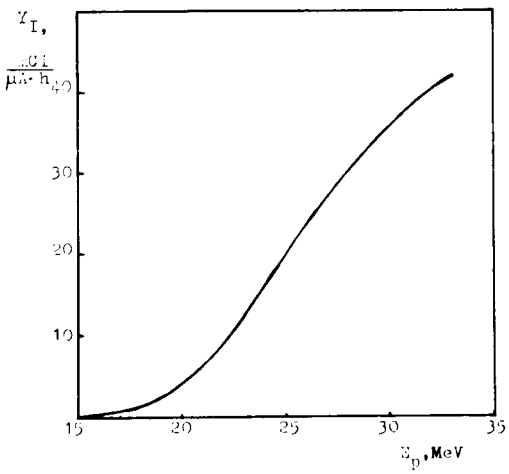

Fig. 1. Yield of ^{123}I from the thick target vs the incident proton energy, calculated for 6.6 hours after the end of radiation.

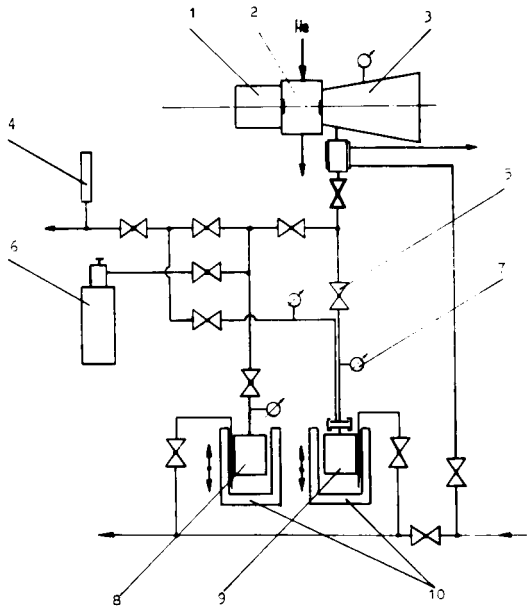

Fig. 2. Target facility for ^{123}I production: 1- diagnostic box; 2- foil window block; 3- gas target; 4- vacuum gauge; 5- valve; 6- transportation vessel; 7- pressure gauge; 8- gas storage vessel; 9- decay vessel; 10- Dewar vessel.

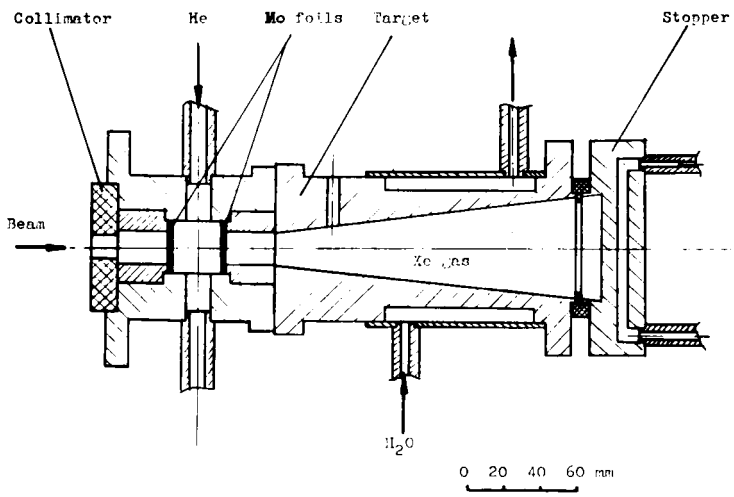

Fig. 3. Gas target.