

ABOUT MODEL EXPERIMENTS ON PRODUCTION OF MEDICAL RADIONUCLIDES AT THE IBR-2 REACTOR

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Abstract

Possibilities of carrying out of model experiments on production of medical radionuclides at the irradiation facility on the experimental beamline №3 of the IBR-2 reactor are discussed in the current paper. The measurements of aliquot spectra purify after the irradiation of samples of ⁹⁸Mo and ¹³⁰Te original isotopes showed a content with a considerable amount of ^{99m}Tc, ⁹⁹Mo and ¹³¹I radionuclides with an activity from $3.7 \cdot 10^6$ Bq to $1.57 \cdot 10^7$ Bq. The obtained effective experience and the positive results of the experiment show that the neutron spectrum at the IBR-2 reactor is appropriate for implementing such kind of experiments on production of medical radioisotopes.

Introduction

The infrastructure for production of medical radioisotopes mostly consists of research reactors or accelerators, as well as related processing facilities suggested for the ⁹⁹Mo, ^{99m}Tc parent isotope production [1]. From 30 to 40 million scannings are produced per year using ^{99m}Tc which amounts 80% of all the procedures of nuclear medicine. Nevertheless, facilities designed for producing ⁹⁹Mo on the basis of reactors are frequently used for producing other isotopes, such as, for instance, ¹³¹I.

Radionuclides ^{99m}Tc and ¹³¹I are widely used in nuclear medicine for early detection of different kinds of diseases. For instance, ^{99m}Tc is used for the diagnosis of oncological, cardiovascular and other diseases, and ¹³¹I – for detection and treatment of thyroid diseases at treating diffuse toxic goiter (Graves' disease), etc.

^{99m}Tc is produced from ⁹⁹Mo by a generator method in the result of decay of the parent radioisotope ⁹⁹Mo [2], and ¹³¹I is the daughter product of β -decay nuclide ¹³¹Te. Such types of isotopes are produced, as a rule, by target irradiation in nuclear reactors; see for instance, [3]. Whereas, more than 95% of the radioisotope ⁹⁹Mo is produced using highly enriched uranium containing isotope ²³⁵U \approx 90% (nuclear reaction ²³⁵U (n,f)⁹⁹Mo). About 50 kg highly enriched uranium is used per year by commercial producers of ⁹⁹Mo. Radiochemical processing, as well as purification of the gained isotopes faces the handling of high-activity materials and takes a long time to involve the utilization of radioactive wastes, the summary activity of which essentially increases the activity of targeted radioisotope [4]. Ecological tasks, as well as the problem handling long-lived radioactive wastes are the major constraining factors at realizing this method of producing radioisotope ⁹⁹Mo. However, despite it, the production of

^{99}Mo using nuclear reaction $^{98}\text{Mo} (n,\gamma)^{99}\text{Mo}$ at molybdenum target irradiation accounts for 5% of the total number of the produced isotope.

As to radioisotope ^{131}I , it may be produced, as ^{99}Mo , by two methods: in nuclear reactions $^{235}\text{U} (n,f)^{131}\text{I}$ and $^{130}\text{Te} (n,\gamma)^{131}\text{Te} \rightarrow ^{131}\text{I}$, yet it is generally produced in the result of tellurium target irradiation with thermal neutrons, i.e. from the capture reaction $^{130}\text{Te} (n,\gamma)^{131}\text{Te} \rightarrow ^{131}\text{I}$.

The current requisition on ^{99}Mo meets the research reactors or accelerators with overall productivity of about $4.3 \cdot 10^6$ Ci at the end of processing and processing facilities with overall productivity of about $3.8 \cdot 10^6$ Ci after release and radiochemical purification. Shutdown of reactors because of service life completion will in the nearest future inevitably lead to the loss of productivity in industry.

For compensating the loss, we should consider the possibilities of producing isotopes at existing facilities, for instance, at the fast pulsed research reactor IBR-2, with a power 2MW operating at FLNP JINR (Dubna, Russia). The IBR-2 reactor possesses neutron flux density (10^{13} n/cm 2 ·s – time averaged value, 10^{16} n/cm 2 ·s – in pulse) as compared to leading world sources.

That is why the main objective of the current paper is the study of possibilities of using the IBR-2 reactor aimed at developing radioisotopes on the example of ^{99}Mo ($^{99\text{m}}\text{Tc}$) and ^{131}I .

Irradiation facility at the IBR-2 reactor and the description of experiment

The device and work principle of the irradiation facility of the IBR-2 reactor, as well as the neutron spectrum generated by them are presented in [5, 6]. Samples for irradiation are installed at some distance from the thermal moderator (Fig.1) at the end of aluminum profile of the irradiation facility of the IBR-2 reactor. The maximal value of fast neutron flux density (with energy over 0.4 MeV), equal to $\sim 2 \cdot 10^{12}$ n/cm 2 ·s, reaches about 40mm from the surface of the thermal moderator when the end of the aluminium profile (3) is located at minimum-possible distance. The neutron spectrum in this case consists of $\sim 50\%$ resonance, $\sim 25\%$ fast and $\sim 25\%$ thermal neutrons.

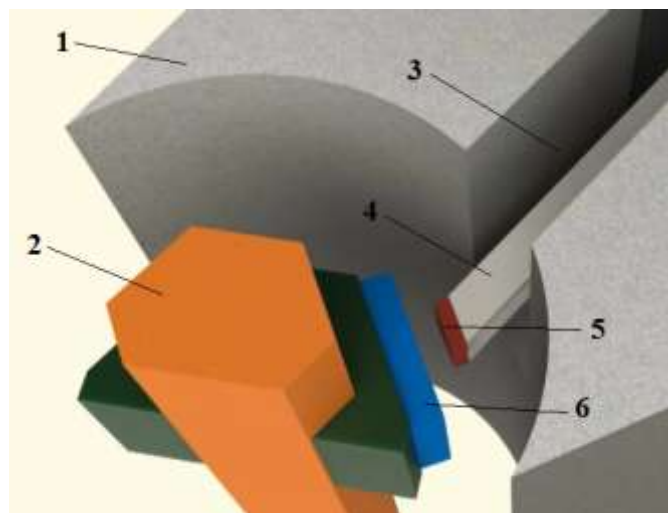


Fig.1. Aluminium profile of the irradiation facility near the water moderator of the IBR-2:
1 – biological shield, 2 – active core, 3 – 3rd experimental beamline, 4 – aluminium profile of the irradiation facility, 5 – sample, 6 – thermal moderator.

The samples ^{98}Mo and ^{130}Te in the form of white metal powder with a mass of 10 and 50 mg have been located in hermetic-sealed transparent glass granules (Fig.2) and installed at a distance of 40mm from the IBR-2 water moderator. The sample irradiation took place within 262 hours on reactor power about 2MW; at the end of irradiation neutron fluence of about $1.3 \cdot 10^{18} \text{ n/cm}^2 \cdot \text{c}$ was gained (equivalent to irradiation dose $\sim 160 \text{ MGy}$).

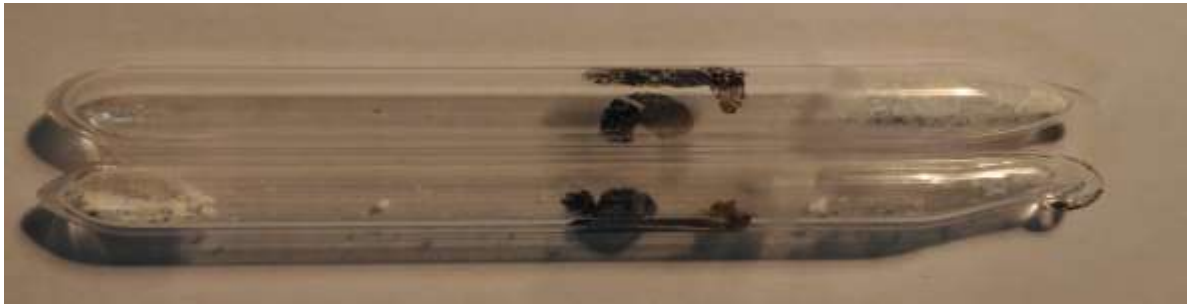


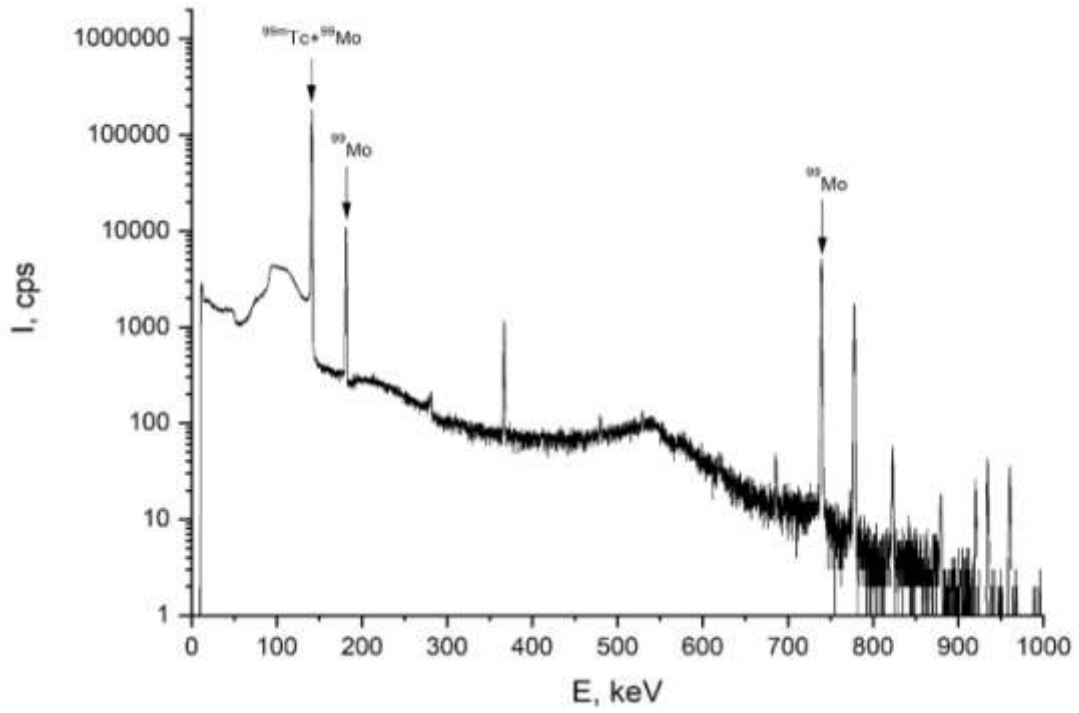
Fig. 2. Isotopes' samples.

Results and discussion on them

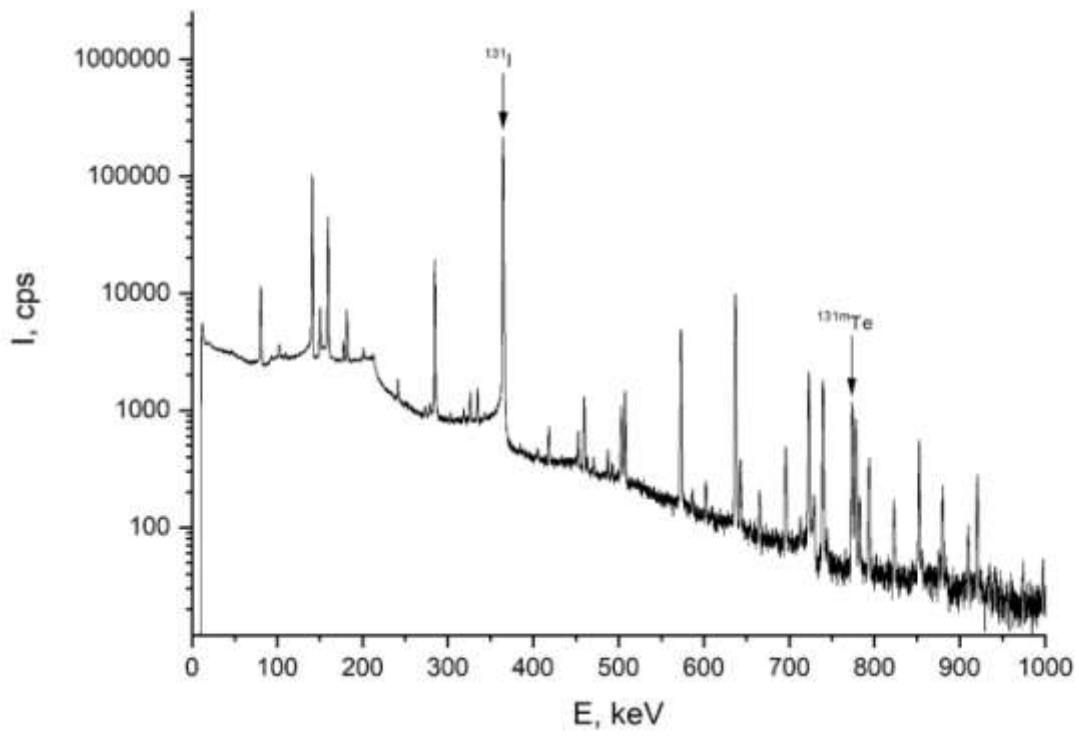
For determining the activity of targeted radionuclides ^{99}Tc , ^{99}Mo and ^{131}I measurements on gamma-spectra of irradiated samples have been carried out. The sample processing started in 86 hours after the end of irradiation. For this purpose, the content of granules was being dissolved in 5ml 5mole/l KOH within 2hours. Afterwards, aliquots with a volume of 50 mkl per have been selected from the produced solutions and steamed on a thin teflon substrate. The measurements have been carried out on a standard coaxial HPGe gamma-spectrometer manufactured by the CANBERRA. The typical aliquot spectra are presented in Fig. 3. From the results of measurements activities being produced at the irradiation of initial samples Mo and Te were determined at the moment of irradiation end from $3.7 \cdot 10^6 \text{ Bq}$ to $1.57 \cdot 10^7 \text{ Bq}$ (Table 1).

Table 1. Activity of radionuclides included in the samples ^{98}Mo and ^{130}Te after irradiation

| Sample | Radionuclide | Calculated activity, Bq | Actual activity, Bq |
|-------------------|---------------------------|-------------------------|---------------------|
| ^{98}Mo | ^{99}Mo | $5.14 \cdot 10^7$ | $1.57 \cdot 10^7$ |
| | $^{99\text{m}}\text{Tc}$ | $5.14 \cdot 10^7$ | $1.55 \cdot 10^7$ |
| ^{130}Te | $^{131\text{m}}\text{Te}$ | $7.83 \cdot 10^5$ | $7.42 \cdot 10^4$ |
| | ^{131}I | $5.42 \cdot 10^6$ | $3.70 \cdot 10^6$ |
| | $^{129\text{m}}\text{Te}$ | $6.40 \cdot 10^5$ | $5.81 \cdot 10^5$ |
| | ^{129}Te | $6.40 \cdot 10^5$ | $3.1 \cdot 10^5$ |
| | ^{127}Te | $3.22 \cdot 10^5$ | $3.13 \cdot 10^5$ |
| | $^{123\text{m}}\text{Te}$ | $3.81 \cdot 10^5$ | $3.71 \cdot 10^5$ |
| | $^{121\text{m}}\text{Te}$ | $1.23 \cdot 10^4$ | $1.2 \cdot 10^4$ |
| | ^{121}Te | $2.1 \cdot 10^5$ | $1.77 \cdot 10^5$ |



(a)



(b)

Fig. 3. Gamma spectra of Mo (a) and Te (b) samples.

The gained results allow to confirm that the IBR-2 experimental beamline №3 may be used as a field for producing medical radioisotopes ^{99m}Tc , ^{99}Mo and ^{131}I . The obtained effective experience and positive results of the experiment can be used for implementing experiments on the production of rather wide range of radioisotopes on the IBR-2 reactor as well.

References

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