PRODUCTION OF ISOTOPES $^{184}$Re, $^{186}$Re AND $^{188}$Re AT LINEAR ELECTRON ACCELERATORS OF NSC KIPT


IHEPNP NSC KIPT

Akademicheskaya 1, Kharkov, Ukraine

This paper presents the preliminary results on determining the values of specific activity of radionuclides $^{184}$Re, $^{186}$Re and $^{188}$Re. Irradiation of Re targets of a natural isotope composition with gamma-quanta and neutrons was conducted at NSC KIPT linear accelerators. Possible levels of activity of the above-mentioned radionuclides are forecasted.

PACS number: 25.20.Lj

It is known that in the world nuclear medicine more than 80% of diagnostic means are radiopharmaceuticals based on $^{99m}$Tc. Developed-to-perfection technologies for commercial production of $^{99m}$Mo $\rightarrow$ $^{99m}$Tc generators are based on a reactor method of $^{99}$Mo production. However, due to a comparatively short half-period of $^{99m}$Tc, as well as, quick accumulation of its decay product—$^{99}$Tc, deteriorating the diagnosis quality this element can not be put in a row of ideal ones [1].

Therefore, in the world practice one observes a tendency to discover new radionuclides having higher characteristics as labels for radiopharmaceuticals [2]. For example, one of promising radionuclides is an isotope $^{186}$Re having, as compared with $^{99m}$Tc, a higher complex-forming ability and a high trophy characteristic. An optimum value (137 keV) of the energy of $\gamma$-quanta emitted, short half-period and absence of accompanying radiation makes this isotope rather promising. The present work is aimed for obtaining the data on the values of the specific activity of Re isotopes produced at NSC KIPT accelerators under different irradiation conditions.

As targets for isotope production we have used metallic Re in the form of plates and fine dispersed powder. The chemical purity of initial targets was no less than 99.99%. The targets were packed in containers from the aluminum foil 0.1 mm thick.

Accelerators were operating under the following irradiation conditions:

- electron energy $- 25$ MeV; 11.5 MeV
- mean beam current $- 500 \mu A$
- irradiation time $- 20$ hours; 105 min.

Prepared and weighed sample-targets were placed at the accelerator EPOS at a distance of ~90 cm from the exit foil of the accelerator. The cassettes with other targets from Re metallic Re in the form of plates and fine dispersed powders were placed ahead other targets immediately under the electron beam. At the accelerator KUT similar targets from Re were placed ahead other targets immediately under the electron beam. A bremsstrahlung converter was not set after radiation treatment were placed ahead of the cassettes with other targets from the aluminum foil 0.

Irradiation of Re targets of a natural isotope composition with gamma-quanta and neutrons was conducted at NSC KIPT linear accelerators under different irradiation conditions:

- electron energy  – 25 MeV; 11.5 MeV
- mean beam current  – 500 $\mu A$
- irradiation time  – 20 hours; 105 min.

When evaluating the sample activity, the detector $\eta$ was the essential factor. It was determined as a relationship between the quantity of quanta detected in the photopeak and the quantity of quanta radiated from the $\gamma$-source with a known activity. With such determination of the efficiency it was not necessary to evaluate in each case a solid angle being covered by the detector when changing the source position. To determine $\eta$ we have used a set of standard $\gamma$-sources comprising $^{22}$Na, $^{137}$Cs, $^{54}$Mn, $^{241}$Am with energies of $\gamma$-lines

\begin{equation}
N_0 = \frac{N}{1 - N \cdot (\tau/\tau_f)^f}.
\end{equation}
511, 1275, 661, 834, 59.5 KeV, respectively.

Results on the detector efficiency measured as a function of the γ-quantum energy at different distances from the source are represented in Fig. 1.

The radionuclide activity $A_0$ at the instant of irradiation stopping was calculated by the formula

$$A_0 = \frac{A}{\eta \cdot I \cdot m \cdot k \cdot e^{-\lambda t}}$$  \hspace{1cm} (5)

where $\eta$ is the efficiency of γ-quantum detection, $I$ is the average current falling onto the sample, $A_0$ is the specific activity of the sample at the instant of stopping irradiation, $m$ is the target mass, $k$ is the coefficient of γ-quantum multiplicity, $A$ is the number of γ-quanta detected in the time $t$ after irradiation stopping, $\lambda$ is the radionuclide decay constant.

Initially irradiation of the Re sample in the form of a plate was performed at the accelerator EPOS. When measuring the activity of samples in the form of a powder at the accelerator KUT are calculated by the following data: irradiation, specific activity of the sample at the instant of stopping was calculated by the formula

$$A_0 = \frac{A}{\eta \cdot I \cdot m \cdot k \cdot e^{-\lambda t}}$$  \hspace{1cm} (5)

In Fig. 2 is a part of the radiation spectrum of the Re sample irradiated at the accelerator KUT during 105 min. For the illustration be clearer the γ-lines of $^{184}$Re with energies of 792 and 903 keV are not shown.

An important result is the presence of the 155 keV peak belonging to $^{188}$Re. This isotope formed from $^{187}$Re, as a result of neutron capture, has comparatively short half-life and is interesting for radiological investigations. A traditional method of $^{188}$Re production is the $^{186}$W based generator obtained in nuclear reactors from $^{186}$W (28%) by the scheme $^{186}$W (n,γ)→$^{187}$W(n,γ)→$^{188}$W(69 days)→$^{188}$Re. Such a two-step process of $^{188}$W production requires availability of high-intensity neutron flows and reactor irradiation of long duration. The results obtained on the $^{188}$Re radionuclide shows a possibility to produce this radionuclide at a linear electron accelerator as an alternative of the reactor method that is currently urgent for the nuclear medicine of Ukraine. Irradiation of Re targets with neutrons is more preferable than with γ-quanta because there formed are only isotopes $^{186}$Re and $^{188}$Re without $^{188}$Re.

The levels of induced activity of isotopes at the accelerator KUT are calculated by the following data: irradiation during 105 min, sample mass is 250 mg, beam is spread on the area of 300 m², surface of the Re sample is 0.3 cm². We have obtained the following data on the specific activity of radionuclides: $^{186}$Re – 4.3⋅10⁶ Bq/g μA, $^{188}$Re – 5.3⋅10⁷ Bq/g μA. At the accelerator EPOS the samples were irradiated during 20 hours. Rest of parameters for calculating the specific activity were similar to parameters of irradiation at the accelerator KUT. The value of activity of radionuclide $^{186}$Re was 7.2⋅10⁶ Bq/g μA. The values of activity allow one to make a conclusion about expedience to continue a research in this direction. Let us note that this experiment was preliminary since the target irradiation was conducted simultaneously with other radiating programs without applying complementary converters and neutron-producing targets. The specific activity of produced isotopes can be increased, firstly, by applying the optimized converter of bremsstrahlung irradiation (Ta (Z=73), thickness ~2 mm); secondly, by increasing the duration of sample irradiation and by focusing the electron beam onto the converter or neutron-producing tar-

### Table 1

<table>
<thead>
<tr>
<th>Nuclear reaction</th>
<th>$T_{1/2}$</th>
<th>$E_{\text{thres}}$ (MeV)</th>
<th>$E_{\gamma}$ (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{185}$Re(γ,n) $^{184}$Re</td>
<td>38 days</td>
<td>7.8</td>
<td>111(17%), 792(36%), 894(16%), 903(36%)</td>
</tr>
<tr>
<td>$^{185}$Re (γ,n) $^{186}$Re</td>
<td>90 hours</td>
<td>7.3</td>
<td>137(12%)</td>
</tr>
<tr>
<td>$^{185}$Re (n,γ) $^{184}$Re</td>
<td>90 hours</td>
<td>-</td>
<td>137(12%)</td>
</tr>
<tr>
<td>$^{185}$Re (n,γ) $^{184}$Re</td>
<td>17 hours</td>
<td>-</td>
<td>155(21%)</td>
</tr>
</tbody>
</table>

![Fig. 1. Detector efficiency as a function of γ-quantum energy at different distances from the source: 5.5 mm, 60 mm, 100 mm.](image)

![Fig. 2. Spectrum of Re irradiated at the accelerator KUT.](image)
get that, according to calculations, should increase the specific activity approximately by a factor of $10^3$. This enables one to begin experiments on preparing and using farmaceuticals labelled with isotopes $^{186}$Re and $^{188}$Re.

**REFERENCES**


