ESTIMATION OF Os, Ir, Sc, In ISOTOPE PRODUCTION AT ELECTRON LINEAR ACCELERATORS


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PACS: 29.17.+w

Preliminary data on the production of medical radionuclides $^{47}$Sc, $^{114}$In, $^{192}$Ir and $^{191m}$Os by the photonuclear method are reported. The targets were irradiated in the bremsstrahlung beam of the NSC KIPT accelerator LU-20 at an accelerated electron energy of 29 MeV and a beam current of 10 μA. The required isotopes were produced in the following channels of nuclear reactions: $^{51}$V($\gamma$,$\alpha$)$^{47}$Sc; $^{48}$Ti($\gamma$,$p$)$^{47}$Sc; $^{191}$Ir($\gamma$,$n$)$^{190}$Ir; $^{191}$Os($\gamma$,$n$)$^{190}$Os; $^{191m}$Os; $^{197}$I($\gamma$,n)$^{194}$In. The useful product yields (specific activities) at the end of irradiation, normalized to 1 hour of target irradiation at an average beam current of 1 μA, were obtained.

1. INTRODUCTION

An accumulated wide experience on isotope production and separation has made it possible to substantially extend a range of radionuclides that can be used for nuclear medicine purposes. More stringent requirements on radiation load reduction for both the patients and the clinic personnel play an important part in introduction of new-generation radionuclides into medical practice. At present, there is a world-wide search for new diagnostic and therapeutic isotopes that would have acceptable characteristics, in particular, a high tropic property, and would not involve high-level wastes in their production. A great quantity of radioactive wastes during production by the reactor method. A qualitative difference in the utility of new-generation radionuclides was dictated by the possibility of radiochemical separation of the required isotope from the target matrix. Apart from the fact that $^{47}$Sc has the 159 keV γ-line that is acceptable for diagnostics, this isotope being the β-radiator holds promise for radioimmunotherapy of tumors [4].

To obtain the data on the radiation field at the location site of each target, the targets were supplied with “check test pieces”. The last ones presented thin copper foils that were cut out to repeat the shape of the target; each check test piece was packed together with its respective target. The “total” check test piece had a size knowingly greater than the cross section of the γ-beam in the target-disposed plane.

The Os, V, Ti, In, Ir targets were irradiated at the electron linac LU-20 at accelerated electron energy of 29 MeV. The residual-activity γ-spectra of the samples were measured at the spectrometry bench with the use of the 100 cm$^3$ Ge(Li) detector [6].

After irradiation, the activity of each check test piece at the moment of irradiation end was measured. The ratio of the activity of an individual check test piece to the activity of the common check test piece is approximately equal to

2. MATERIALS AND METHODS

The table below characterizes some promising isotopes, the production of which seems expedient at the ELA [4]. To determine experimentally the levels of activity produced, Os, Ir, Ti, V, Ni, In targets were chosen. Metal samples of In, Ir and Os, as well as Ni of natural composition were used, while Ti and V targets were chosen to produce $^{47}$Sc isotopes. This choice of radionuclides was dictated by the possibility of radiochemical separation of the required isotope from the target matrix.

The common check test piece is approximately equal to the moment of irradiation end was measured. The ratio of the activity of an individual check test piece to the activity of the common check test piece is approximately equal to

<table>
<thead>
<tr>
<th>No</th>
<th>Isotope</th>
<th>Radiation energy, keV</th>
<th>Half-life</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$^{114}$In</td>
<td>590</td>
<td>159</td>
<td>3.4 days</td>
</tr>
<tr>
<td>2</td>
<td>$^{191}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>3</td>
<td>$^{191}$Os</td>
<td>2135</td>
<td>155</td>
<td>16.9 hours</td>
</tr>
<tr>
<td>4</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>5</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>6</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>7</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>8</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
<tr>
<td>9</td>
<td>$^{192}$Ir</td>
<td>1080</td>
<td>137</td>
<td>90.6 hours</td>
</tr>
</tbody>
</table>
the γ-beam utilization factor. The beam utilization factor is quantitatively determined by the ratio of the γ-quan-
tum flux passing through the target section to the total γ-
quantum flux passing through the target-disposed plane. According to preliminary estimates, the error of deter-
mining the beam utilization factor due to different pho-
tonuclear reaction thresholds does not exceed 15%.

3. RESULTS AND DISCUSSION

The gamma-radiation spectra from the Ir target ir-
radiated for 1 hour are presented in Fig.1. Fig.1,a shows the 186 keV, 361 keV, 371 keV, 407 keV, 605 keV γ-
lines of 192 Ir isotope. The next measurement of the spec-
trum was performed after a lapse of 150 days (i.e., 2 half-
lives of 192 Ir isotope). For this period of time the 190 Ir isotope decays practically completely, and the radiation spectrum of the target shows only the lines of the 192 Ir isotope, as can be seen in Fig.1,b.

The calculations of specific activity of the men-
tioned nuclides give the following values: 8.7·10⁵ Bq/g·μA for 192 Ir and 4·10⁶ Bq/g·μA for 190 Ir.

The isotope 47 Sc was produced by means of the fol-
lowing two reactions: 48 Ti(γ,p)47 Sc and 51 V(γ,α) 47 Sc. Fig.2 shows the spectra from irradiated titanium and vanadium targets. The two spectra provide a reliable identification of the isotope 47 Sc (T1/2=3.4 days) by the 159 keV γ-line. The comparison between the spectra from vanadium and tantalum targets suggests the conclusion about a preferential use of the titanium target, since its radiation spectrum has a better purity as compared with the spectrum of irradiated vanadium. Furthermore, the comparison between specific activity values of 47 Sc has shown that with the use of the titanium target the specific production of 47 Sc is higher than in the vanadium target case. The calculated specific activity values of different radionuclides are given in Table 2.

Fig.1. Gamma-radiation spectra of Ir target: 2 days (a) and 150 days (b) after irradiation

Fig.2. Gamma-radiation spectra of irradiated titanium (a) and vanadium (b) targets

<table>
<thead>
<tr>
<th>No</th>
<th>Reaction</th>
<th>Target mass, g</th>
<th>Initial isotope fraction</th>
<th>Average beam current, μA</th>
<th>Beam utilization factor K</th>
<th>Specific activity Bq/g·μA</th>
<th>Specific activity without K taken into account, Bq/g·μA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>192 Os(γ,n)191 Os</td>
<td>0.54</td>
<td>0.41</td>
<td>9</td>
<td>0.126</td>
<td>1.19·10⁵</td>
<td>1.51·10⁴</td>
</tr>
<tr>
<td>2</td>
<td>51 V(γ,α)47 Sc</td>
<td>0.14</td>
<td>0.99</td>
<td>9</td>
<td>0.118</td>
<td>1.90·10⁵</td>
<td>2.24·10⁴</td>
</tr>
<tr>
<td>3</td>
<td>115 In(γ,n)114 In</td>
<td>0.2</td>
<td>0.96</td>
<td>9</td>
<td>0.816</td>
<td>1.91·10⁵</td>
<td>1.56·10⁵</td>
</tr>
<tr>
<td>4</td>
<td>193 Ir(γ,n)192 Ir</td>
<td>0.07</td>
<td>0.615</td>
<td>57</td>
<td>0.155</td>
<td>8.68·10⁵</td>
<td>1.34·10⁵</td>
</tr>
<tr>
<td>5</td>
<td>51 V(γ,α)47 Sc</td>
<td>0.14</td>
<td>0.99</td>
<td>57</td>
<td>0.18</td>
<td>1.27·10⁵</td>
<td>2.28·10⁴</td>
</tr>
<tr>
<td>6</td>
<td>48 Ti(γ,p)47 Sc</td>
<td>0.045</td>
<td>0.74</td>
<td>57</td>
<td>0.75</td>
<td>4.21·10⁵</td>
<td>3.16·10⁵</td>
</tr>
<tr>
<td>7</td>
<td>192 Os(γ,n)191 Os</td>
<td>0.54</td>
<td>0.41</td>
<td>57</td>
<td>0.126</td>
<td>1.45·10⁵</td>
<td>1.82·10⁴</td>
</tr>
</tbody>
</table>

Table 2. Specific production values of some radionuclides

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2006. № 3.
4. CONCLUSIONS

1. From the analysis of publications it has been established that nuclear medicine tends to turn to radionuclides of new generation, and a list of radionuclides that can be produced at electron linacs has been drawn up (Table 1). Of most interest are the isotopes $^{57}$Co, $^{60}$Co, $^{47}$Sc, $^{114m}$In, $^{188}$Re, $^{188}$Re, $^{190}$Os, $^{190}$Os, $^{192}$Ir, which have intense $\gamma$-lines in the energy range used for medical purposes. A possible use of unenriched targets of natural composition is an additional factor in favor of isotope production by the photonuclear method.

2. The value of specific activity produced in irradiated targets is high enough to consider the photonuclear method of isotope production as an alternative to the cyclotron technique.

REFERENCES


ОЦЕНКА НАРАБОТКИ ИЗОТОПОВ Os, Ir, Sc НА ЛИНЕЙНЫХ УСКОРИТЕЛЯХ ЭЛЕКТРОНОВ

А.Н. Довбня, Г.П. Ковтун, А.В. Торговкин, В.Л. Уваров, Б.И. Шраменко

Представлены предварительные экспериментальные результаты по наработке медицинских радионуклидов $^{57}$Sc, $^{114m}$In, $^{190}$Ir и $^{190}$Os, $^{192}$Os фотоядерным методом. Облучение мишений проводилось на пучке тормозного излучения ускорителя ЛУ-20 ННЦ ХФТИ при энергии ускоренных электронов 29 МэВ и токе пучка 10 мкА. Необходимые изотопы образуются по следующим каналам ядерных реакций $^{51}$V($\gamma$,n)$^{50}$Sc; $^{48}$Ti($\gamma$,p)$^{47}$Sc; $^{191}$Ir($\gamma$,n)$^{190}$Ir; $^{190}$Os($\gamma$,n)$^{190}$Os, $^{191}$Os; $^{115}$In($\gamma$,n)$^{114}$In. Измерены значения выхода (удельной активности) полезного продукта на момент окончания облучения, нормированные на 1 час облучения мишений при величине среднего тока пучка 1 мкА.

ОЦЕНКА НАПРАВЛЯНИЯ ИЗОТОПОВ Os, Ir, Sc НА ЛИНЕЙНЫХ ПРИСКОРЮВАЧАХ ЭЛЕКТРОНОВ

А.М. Довбня, Г.П. Ковтун, О.В. Торговкин, В.Л. Уваров, Б.И. Шраменко

Надано попередні експериментальні результати по направлянню медичних радіонуклідів $^{114}$In, $^{190}$Ir та $^{190}$Os, $^{191}$Os фотоядерним методом. Опірмінення мішень проведилось на пучку гальмівного випромінювання прискорювача ЛП-20 ННЦ ХФТИ при енергії прискорених електронів 29 МеВ та струму пучка 10 мкА. Необхідні ізотопи утворюються за наступними каналами ядерних реакцій $^{51}$V($\gamma$,n)$^{50}$Sc; $^{48}$Ti($\gamma$,p)$^{47}$Sc; $^{191}$Ir($\gamma$,n)$^{190}$Ir; $^{190}$Os($\gamma$,n)$^{190}$Os, $^{191}$Os; $^{115}$In($\gamma$,n)$^{114}$In. Вимірні виходи (питомої активності) корисного продукту на момент закінчення опромінення, що нормовано на 1 годину опромінення мішений при середньому струмі пучка 1 мкА.