OPTIMIZATION STUDY ON PRODUCTION OF Mo-99 USING HIGH POWER ELECTRON ACCELERATOR LINAC

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Abstract

Molybdenum99 is used for preparing ^{99m}Tc, which is the most widely used isotope in nuclear medicine. As a recent and now shortages in reactor-based supplies of ^{99}Mo/^{99m}Tc and also some problems due to the time limitation in a direct production approach such as ^{100}Mo(p,2n)^{99m}Tc reaction by cyclotrons, many of developed countries have started the plan to produce this type of radioisotopes based on the production of non-reactor methods, especially by linac. In this study, the investigation on ^{99}Mo production based on high power electron linac as an alternative approach has been performed, in which the use of ^{100}Mo(gamma, n)^{99}Mo (photoneutron production) has been proposed.

INTRODUCTION

The concern of isotope crisis can be illustrated by reviewing the published articles about this topic in the recent years [1, 2]. ^{99m}Tc is an important and most useful isotope in diagnosis nuclear medicine because of short half-life (6 hours) 140 keV gamma ray emission and the ability of combination with 31 different carrier molecules. It is appropriate for diagnose imaging of different organs like brain, thyroid, liver etc. So, extensive researches are being in progress for production of ^{99m}Tc.

Many methods with own advantages and disadvantages have been proposed to achieve the optimized production yield. . For example, in the reactor-based method (with appropriate yield but high cost) most of research reactors are in end of their operational lifetime (such as NRU in Canada), and will be shut down in near future (NRU ceases production in 2018) [3]. In addition, not only the production of ^{99m}Tc, but also the production of most radioisotope supplies will be a serious problem. In should be noted that most of these reactors require high enrichment fuel. Therefore, scientists and engineers are trying to reach alternative and useful methods, specially based on accelerators. Using accelerators has low efficiency, but it is very safe and needs low cost, of course the efficiency can be increased by using the specific designs.

ADVANTAGES AND DISADVANTAGES

The reactor-based methods have two primary solutions: 1) Separation from fission fragments (HEU or LEU fuel in research reactors) or, 2) neutron activation of molybdenum (natural molybdenum or ^{98}Mo) in the core of a power or a research reactor.

Construction and maintenance of a reactor is a time consuming and an expensive process. In addition, monitoring the production process in this method is very complex and expensive. It should be noted that only about 6-7 percent of dangerous fission fragment include ^{99m}Tc.

Direct production from ^{100}Mo (p, 2n) ^{99mTc} reaction in a different methods using cyclotron has some advantages such as the low environmental hazards and less waste management difficulties. However, due to the short half-life of ^{99m}Tc, the direct production method can be used only in nuclear medicine centres near cyclotron facilities or have to be used the small cyclotron in hospitals or nuclear imaging clinics. Small cyclotrons' energy is around of 15MeV that is capable of providing the ^{99m}Tc requirement of the unit [4].

Nevertheless, in the accelerator-based method using electron-linac, the primary product is ^{99}Mo (which is produce by (gamma, n) interaction from ^{100}Mo) that decays into ^{99m}Tc after 66h half-life with beta decay reaction. This process can provide enough time for the distribution and preparation process. Electron linac has less radiative pollution and also less cost than the other methods. Based on the MEVEX Company system, the production of 191Ci Mo requires the 33MeV electron linac with 120 kWh power [5].

ELECTRON LINAC-BASED APPROACH

In this method, different approaches have been investigated. The main and general way is two-stage approach (W as a photon converter and ^{100}Mo as a photoneutron target). The other method is one-stage approach (based on using a molybdenum as a photon converter and also photoneutron target) [6]. Also, in cases that suitable neutron flux is accessible, ^{98}Mo target can be used as a thermal neutron absorption target.

As a first step, the design of photon converter should be determined. In this study, the one-stage approach is chosen for 30 MeV electron linac and cylindrical and hemispherical geometries are considered for ^{100}Mo target. Those geometries are compared according to the photoneutron yield that relates to ^{99}Mo production.

The results of the simulation by MCNP Monte Carlo code show that the hemispherical geometry in the optimized yield is 14.33 % greater than cylindrical geometry. For hemispherical geometry, the optimized geometry for obtaining maximum yield is 3.6 cm in radius, in which more than this radius the photoneutron yield remains constant (increases less than 10% as shown in Fig. 1). Also, the inverse geometry (hemisphere 2 in Figure 2) lead the greatest yield.

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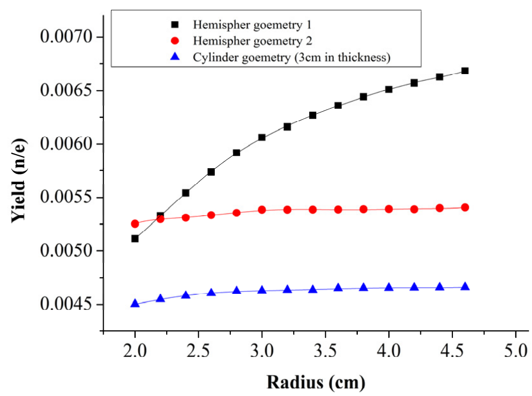

Figure 1: Neutron yield (photoneutron reaction per electron).

As a Fig. 2, the design geometries are shown.

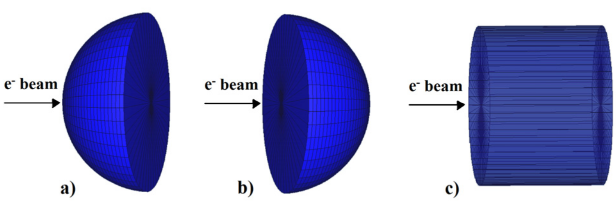

Figure 2: Mo geometries: a) Hemispherical 1. b) Hemispherical 2. c) Cylindrical.

Also, the yield of cylindrical target is calculated for 1 mA electron beam, that shown in Fig. 3. It can be seen that 3 cm in thickness and 1.6 cm in radius can be considered as an optimized dimensions to provide suitable yield.

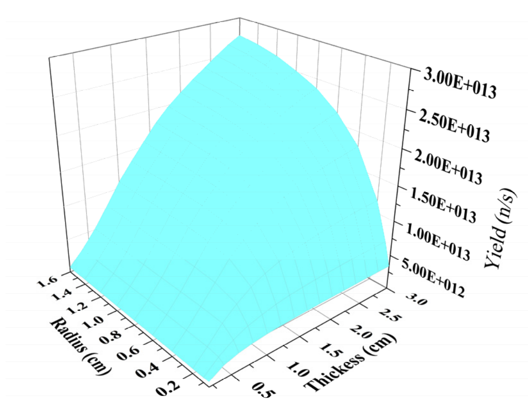

Figure 3: Number of neutron in total volume of target.

CONCLUSION

In this study, the optimized geometry has been investigated for Mo target. Base on the results, hemispherical target including uniform photon converter and photoneutron is proposed. Because the bremsstrahlung photons are attenuated in the target and they are consumed as a photoneutron reaction directly in the target, the yield of photoneutron production increases. For increasing yield of production, it suggests that The low energies bremsstrahlung photons (energy less than 9MeV) that can't participate in photoneutron reaction in the photoneutron target, can utilize in special target such as heavy water (Deuteron photoneutron reaction threshold is 2.22MeV) to produce enough neutron flux.

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