Cyclotron production of ^{94m}Tc via proton-induced reaction on ^{94}Mo target

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Introduction

Positron emission tomography (PET) is a non-invasive medical imaging technology that can generate high resolution images of physiologic functions with clinical application for oncology, cardiology and neurology. ^{94m}Tc (T1/2 = 52 min) decays by β+ (72%) , EC (28%) and therefore is suitable for PET imaging. ^{94m}Tc-based imaging agents to study pulmonary, myocardial and cerebral perfusion as well as renal and hepatobiliary function, to detect blood-brain barrier defect, to image tumor, brain, and bone have been investigated [1, 2]. ^{94m}Tc is employed to detect biological distribution of ^{99m}Tc as a radio medicine in the human body [3-8]. Several methods for ^{94m}Tc production have been developed using cyclotrons in the present work.

Material and Methods

Target Preparation

The natural Molybdenum as a high purity (>99%) MoO_3 powder (10–20 µm particle size) of isotopic composition (92Mo 14.8%; 94Mo 9.3%; 95Mo 15.9%; 96Mo 16.7%; 97Mo 9.6%; 98Mo 24.1% and 100Mo 9.6%), was used as a target material for irradiation at the Isotopes Research Group. The optimum conditions of the sedimentation were obtained with 533 mg of MoO_3, 600μL of methyl cellulose or Ethyl cellulose and 3mL acetone, so, the MoO_3 layer of 11.69 cm2 and 45.81 mg – cm2 was prepared with above conditions. The target bombardment was carried out with an external proton beam of a Cyclotron (IBA-Cyclone 30) at the Agriculture, Medicine and Industrial Research School. According to the ALICE-91[9] and TALYS-1.0[10] codes and published data [11, 12], the proton entrance energy should be less than 15 MeV to get full benefit of excitation function and to avoid the formation of radionuclide impurities. According to SRIM code [13], the target thickness is 929.6 µm for 90° geometry. The all details of target preparation have been discussed in our previous work [14].

Production

Due to less abundance of ^{94}Mo as compare to other its isotopes, the enriched target is not available easily, so, the natural Molybdenum is used as a target. According to Talys code and the experimental data, to take full benefit of the related excitation function and to minimize undesired radionuclide impurities formation, the incident proton energy should be in the 13 - 5 MeV region [15-17]. The production yield of ^{94m}Tc and its impurities are tabulated in the Table 1. The physical thickness of the target (MoO_3) layer is chosen in such a way that for a given beam/target angle geometry the particle exit energy should be 5 MeV. It is advisable to minimize the MoO_3 deposit thickness to perform irradiation on 6° target geometry. In such a case a 97.2 µm MoO_3 layer is recommended. The highest yield of ^{94m}Tc is given by the $^{94}Mo(p,n)^{94m}Tc$ reaction, with Ep= 15–5 MeV protons and an acceptable level of impurity. This is the suitable method for large-scale ^{94m}Tc production using small cyclotrons [18- 20]. Different targets were investigated to produce ^{94m}Tc. A vertical beam target for simultaneous irradiation of molten-enriched $^{94}MoO_3$ and sublimation of ^{94m}Tc was reported, but it was not very successful [20]. This target was sedimented as explained in our previous work [14]. Due to poor heat conduction of target material (MoO_3), during irradiation process at 5 µA proton beam current, the target had been destroyed and some of that has also evaporated. To produce ^{94m}Tc, the natural Molybdenum (metallic powder form) target was bombarded with 15 MeV proton beams which have been extracted with Variable Energy Cyclotron-30 (IBA – Belgium, 15-30 MeV). Identification and assay of gamma-ray

Table 1: Font type and size

Nuclides	Experimental Yield (MBq/μAh)	Theoretical Yield (MBq/μAh)
^{94m}Tc	341.83± 47.86	386.25
^{94g}Tc	46.88±2.82	41.95
^{95g}Tc	58.51±14.63	44.68
^{99m}Tc	32.53±1.13	25.55
$^{96m+g}$Tc	17.26±1.72	------

emitting radionuclides was carried out using a high – purity germanium (HPGe) detector and gamma-ray spectrometry (Canberra TM model GC1020-7500SL). The gamma-ray spectrum of produced radionuclide (^{94m}Tc) and its impurities are shown in the Figure 1. All peaks in the Figure 1 have been analyzed with Fitzpeaks Gamma Analysis (FGA) software and they have identified carefully.

Results and Discussion

Various nuclear reactions for the production of ^{94m}Tc have been suggested. Our available reaction was restricted to ^{94}Mo (p, n) ^{94m}Tc. Deposition of natural metallic powder of Mo on Cu substrate was carried out via two special sedimentation methods for the production of ^{94m}Tc [15]. The present experimental and theoretical results are summarized in Table 1. The experimental production yield of 342(48) MBq/μAh in the present work is in agreement with our theoretical value 386 MBq/μAh which has been calculated by TALYS-1.0 code. The parameters productions of 94mTc via proton bombardment have been reported previously [14].

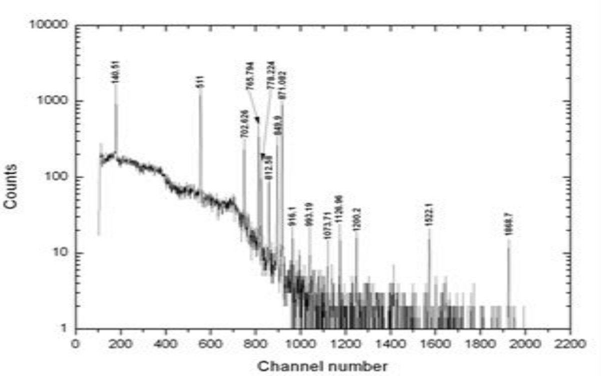

Fig. 1 Gamma Ray Spectrum

by TALYS-1.0 code. The production of ^{94m}Tc via proton bombardment has been reported previously and an overview of some methods is given in Table 1.

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