

Heavy-Ion Induced Production of Medically Relevant Radioisotopes in the $^{14}\text{N} + ^{181}\text{Ta}$ System

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Introduction

Radioisotopes form the backbone of nuclear medicine, with wide application in both diagnosis and therapy commonly used isotopes such as $^{99\text{m}}\text{Tc}$, ^{131}I , ^{18}F , and ^{192}Ir are typically produced in reactors or cyclotrons, while ^{192}Ir is produced in reactors by neutron activation. However, these methods cannot always provide certain proton-rich or neutron-deficient isotopes. Such isotopes are of special value in positron emission tomography (PET), targeted therapy, and radionuclide generator systems. Medical isotopes are usually produced either in reactors through neutron activation or fission [1] or in accelerators using light charged particles [2]. After irradiation, chemical separation methods or radionuclide generators are used to isolate isotopes. The half-lives of these isotopes can vary from minutes (^{18}F : 110 min) to days (^{131}I : 8 d, ^{177}Lu : 6.7d), making both rapid production and separation essential. Heavy-ion (HI) induced reactions provide an alternative route, giving direct access to proton-rich isotopes through xn , pxn and α -emission channels. Irradiation such reactions provide valuable cross-section data, essential for optimizing isotope production pathways.

In this study, we investigate the $^{14}\text{N} + ^{181}\text{Ta}$ system, while previous work has primarily focused on nuclear dynamics [3]. The emphasis is on the production of isotopes relevant to

medical applications. The identified isotopes include those of Au, Hg, Pt, Ir, Os, and Re.

Notably, some of these, such as ^{186}Pt , have recently been explored for theranostic purpose [4]. This makes the present work valuable not only for advancing nuclear physics but also for its translational impact in nuclear medicine.

Experimental Details:

The experiment was performed using a $^{14}\text{N}^{6+}$ beam from the 15UD Pelletron accelerator at IUAC, New Delhi. The beam energy range of $\approx 65\text{--}88$ MeV, corresponding to $\approx 3.6\text{--}4.8$ MeV/nucleon, was suitable for studying HI-induced reactions. High-purity ^{181}Ta foils (99.98%) prepared by rolling were used as targets. Aluminum catcher foils were employed both as beam degraders as well as for collecting recoiling nuclei. The thickness of each target and catcher foil were measured using the α -transmission method with ^{241}Am source (5.486MeV α -particles). Further experimental details, calibration and radioisotopes identification are given in Ref. [3,4]

Experimental cross sections were calculated using the standard equation [4]. Activities were determined from net γ -peak counts, applying corrections for efficiency, branching ratios, and dead time. The overall uncertainty was $\approx 15\%$. Theoretical excitation functions were generated using the PACE4 code. This helped in the

interpretation of the experimental data and in the optimization of beam energies.

Medically Important Isotopes Produced

In the present work, several isotopes of direct medical interest were produced through the $^{14}\text{N} + ^{181}\text{Ta}$ system via multiple evaporation routes. Mercury isotopes ^{192}Hg ($t_{1/2} = 4.8$ h), ^{191}Hg (49 min), and ^{190}Hg (20 min) were produced through 3n, 4n, and 5n reaction channels respectively. They decay to gold isotopes, serving as useful parent isotopes for generator systems [5]. In particular, $^{192}\text{Hg} \rightarrow ^{192}\text{Au}$ chain holds promise for PET imaging. Gold isotopes ^{191}Au (3.18 h), ^{190}Au (42.8 min), and ^{189}Au (28.7 min) were produced through p3n, p4n, and p5n channels respectively.

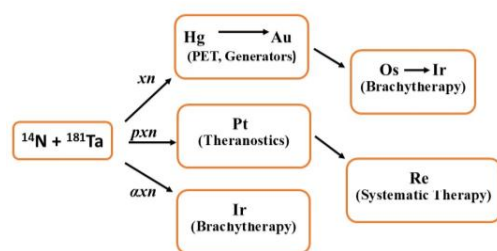


Fig.1. Schematic representation of the production pathways of medically important isotopes in the $^{14}\text{N} + ^{181}\text{Ta}$ system, showing dominant reaction channels (xn, pxn, αxn) leading to the formation of isotopes of Hg \rightarrow Au, Pt, Ir, Os \rightarrow Ir, and Re.

Being β^+ emitters, they are directly relevant for PET imaging and theranostic applications. Further, gold isotopes can also be integrated into nanoparticles, enhancing targeted drug delivery and imaging [5].

The isotopes ^{189}Pt (10.9 h), ^{187}Pt (2.35 h), and ^{186}Pt (2.08 h) were identified through α -emission channels, such as $\alpha 2n$, $\alpha 4n$, and $\alpha 5n$. Although, not yet in wide medical use, these are highly promising. While platinum-based chemotherapy already well established [6] in cancer treatment, radiolabeled Pt isotopes could provide dual action: therapy and imaging [6]. The Iridium isotopes ^{187}Ir , ^{186}Ir , and ^{185}Ir ($t_{1/2} \approx 10\text{--}16$ h) were observed via αpxn type reactions. They may serve as alternatives to ^{192}Ir , which is widely

used in HDR brachytherapy [7]. Their short half-lives would reduce residual activity in treatment facilities. The ^{183}Os ($t_{1/2} \approx 13$ h) was also observed and identified. It decays to ^{183}Ir by β^- emission and could be used in Os-Ir generator systems, similar to the $^{99}\text{Mo}/^{99m}\text{Tc}$ system. [7]. This would allow hospitals to produce iridium isotopes on-site for brachytherapy. The ^{181}Re ($t_{1/2} \approx 19.9$ h) was produced through $\alpha p 3n$ type reactions. It belongs to the same family as ^{186}Re and ^{188}Re , already used in therapy [6]. Its β^- decay and intermediate half-life make it suitable for systemic radiotherapy and bone pain relief [8].

It may now be concluded that, the HI induced reactions in the $^{14}\text{N} + ^{181}\text{Ta}$ system were found to populate a wide spectrum of medically relevant isotopes of Au, Hg, Pt, Ir, Os, and Re through complementary xn, pxn, and αxn channels. Several of these isotopes are directly applicable in PET imaging, brachytherapy, and theranostic, while others show strong promise for future clinical translation. The measured EFs agree with statistical model predictions, with deviations in α -channels due to ICF dynamics playing a role at relatively higher energies. These results establish HI reactions as a complementary and versatile route to novel medical isotopes, bridging nuclear reactions studies with nuclear medicine applications. Additional results and detailed analysis will be discussed in the presentation.

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