Proton-induced production cross section for therapeutic radionuclide ^{192}Ir

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Introduction

Radionuclides play an important role in medical applications in our daily life as well for scientific research [1]. Many radionuclides used in nuclear medicine are produced in accelerators, for example, cyclotrons, or in nuclear reactors. The production of medical radionuclides is an important and constantly evolving topic mainly because it addressed the diagnosis and treatment of various life threatening diseases. The proton- and neutron-induced reactions in accelerators and nuclear reactors are used for the production of radionuclides. The production of a radionuclide requires knowledge of nuclear reaction cross sections. The reaction data are important to obtain the optimum energy range for the production of the radionuclide of interest and to calculate the expected thick target yield of the desired radionuclide. Thorough information of the excitation functions of the relevant nuclear reactions is needed. The nuclear reaction data allow optimization of its production route. The data needed in routine patient-care studies are available and are generally sufficient, the development of non-standard positron emitters and novel low-range highly-ionizing radiation emitters for internal radiotherapy demands considerable amount of new and reliable decay and reaction data.

One of the important radionuclide for medical purposes is ^{192}Ir and is mostly used for treatment of cancer and gynecology. It is widely used in environmental studies, and for the treatment of brachytherapy and cervical cancer. Maximum production of ^{192}Ir is constantly required for treatment and therefore, needs to be produced in large quantities. ^{192}Ir can be produced with proton induced reactions on ^{192}Os target.

In the present work, the production cross sections of ^{192}Ir isotopes through (p,n) and (p,2n) reactions with stable osmium isotopes are calculated in the framework of statistical model. A detailed statistical model analysis has been carried out to describe reactions over a range of proton energies starting from threshold energy of the reaction to 30 MeV.

Theoretical calculation

The cross section for ^{192}Os(p,xn) has been calculated using TALYS 1.95 code [2]. The code consists of nuclear optical model, level density, preequilibrium emission model and several other models. For description of preequilibrium process, exciton model is used. The Koning and Delaroche optical model is employed in the study. Both phenomenological back-shifted Fermi gas model (BFM) as well as microscopic level densities using Skyrme force from Goriely's tables has been used for describing the continuum of levels. These microscopic level densities (LDs) are based on Hartree-Fock (HF) calculations. It is important to consider both the discrete and continuum levels for the various nuclei. For masses of nuclei involved in the calculation, experimental values as have been provided in the TALYS code have been used throughout. More details of similar calculations are presented in Ref. [3].

Results and Discussion

The (p,xn) cross sections for ^{192}Ir have been calculated with different level density models, HF and BFM and they have been compared with available data from literature. Fig. 1 shows the calculated excitation function for ^{192}Os(p,xn) using phenomenological and microscopic LDs and are compared with corresponding data [4,5], Talys-default and TENDL-2019.

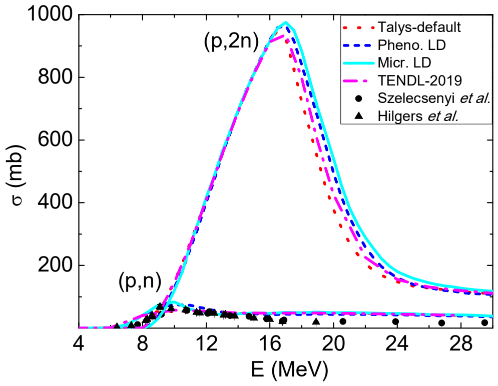

Fig. 1. The calculated excitation function for ^{192}Os(p,n)^{192}Ir and ^{192}Os(p,2n)^{191}Ir reactions using phenomenological and microscopic level densities (LDs) compared with corresponding data [4,5], Talys-default and TENDL-2019. The Koning-Delaroche optical model potential was used in the calculation.

It is observed from the above figure that the calculated (p,n) cross sections using microscopic LD are marginally in better agreement with the (p,n) cross section data and with that of Talys-default, BSFM, and TENDL-2019 calculation. None of the calculations are able to reproduce the experimental data in the tail region of the excitation function; calculations over predict the observed cross section values.

All the calculations are similar to one another for lower energies below the peak cross section for (p,2n) reaction, while they slightly differ for higher energies greater than 18 MeV. The cross section calculated using microscopic LD is shifted to the right as compared to other ones. There are no experimental values available for (p,2n) reaction. It will be interesting to measure the (p,2n) reaction cross section. It is to be noted that the (p,n) cross section is much smaller as compared to that of (p,2n).

Summary

The excitation function for (p,xn) reaction on ^{192}Os have been studied in the framework of statistical model using latest version of nuclear reaction code TALYS-1.95. It appears the calculated (p,n) cross section for ^{192}Os target using microscopic level density is marginally in better agreement with the corresponding cross section data. It is important to carry out experiments for measurements of cross sections for (p,2n) on enriched osmium in the accelerators and validate the predictions of the present work.

References

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