Model based calculation of excitation function of (p,n) reactions for the production of medical radioisotopes (^{64}Cu, ^{169}Yb and ^{192}Ir)

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Introduction

Medical radioisotopes are used for diagnostic and therapeutic purposes as well as metabolism and physiological function research in modern medicine. Production of medical isotope is an important and constantly evolving issue. Cyclotrons and reactors are used for radionuclide production purposes. In general nuclear data known with sufficient accuracies, reaction cross section or excitation function need to pay more attention, especially charged particle nuclear data because they are scarce and scattered. The excitation function data for nuclear reactor production are generally well-known and can be satisfactorily reproduced by nuclear model calculations. Theoretical models of nuclear reactions are generally needed to get the prediction of the reaction cross–sections, in a specific manner if the experimental measurements are unobtainable or are improbably to be produced because of the experimental difficulties.

The present study is aimed to calculate the excitation functions for the production of ^{64Cu}, ^{169}Yb and ^{192}Ir radioisotopes used in medical field to study genetic diseases affecting copper metabolism, such as Wilson's and Menke's diseases; as an internal radiotherapy source for cancer treatment and cerebrospinal fluid studies in the brain respectively. Our study is focused on proton projectile based reaction to produce radioisotopes.

Nuclear Model Calculations

The nuclear model calculations for reactions ^{64}Ni(p,n)^{64}Cu, ^{169}Tm(p,n)^{169}Yb and (p,n)^{192}Ir were performed using TALYS 1.6 codes [1] with energy range from threshold to 20MeV. TALYS 1.6 is a nuclear reaction simulation computer code system program for the analysis and prediction of nuclear reactions of the proton, neutrons, deuteron, triton, gamma, alpha and He particles with a mass of 12 and heavier in the energy range of 1keV-1GeV. All the required inputs like nuclear masses, discrete energy levels, transmission coefficients and nuclear level densities (NLDs) of nuclide involved in the calculations were taken from latest RIPL-3. The global optical model potential which requires calculating the transmission coefficient for proton proposed by Koning and Delaroche has also been used. In the compound and pre-equilibrium models, the level densities of the nuclei involved play a crucial role, thus nuclear level densities can be calculated using phenomenological or microscopic prescriptions. These calculations are referred to as TALYS-default.

Results

The calculated values of the excitation function values of reactions ^{64}Ni(p,n)^{64}Cu, ^{169}Tm(p,n)^{169}Yb and ^{192}Os(p, n)^{192}Ir using TALYS1.6 code are presented in Fig. 1, Fig. 2 and Fig.3 respectively. The excitation function of reactions ^{64}Ni(p,n)^{64}Cu calculated using nuclear model code TALYS1.6 plotted in fig.1 show agreement with experimental values from EXFOR[2]. Nuclear model calculations with all the level density models (ldmodel1-ldmodel5) based data from threshold to 10 MeV energy region are fond in good in agreement with the experimental data available in literature [3-4].. The maximum production yield 39.31 mb was found at E(p)~9 MeV. The radioisotope ^{64}Cu can produced by two reactions: ^{64}Ni(p,n)^{64}Cu and ^{64}Zn(n,p)^{64}Cu but for the production of ^{64}Cu isotope via reaction ^{64}Ni(p,n)^{64}Cu is preferable because it is easier to accelerate a proton easily in cyclotrons and Van-de-Graff generators.

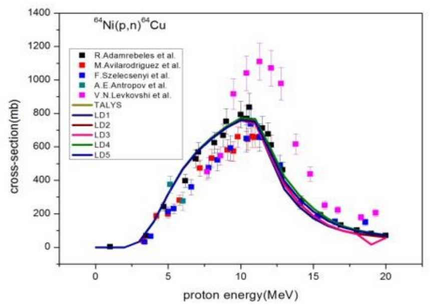

Fig.1: Calculated excitation function of reaction ^{64}Ni(p,n)^{64}Cu and comparison with experimental results.

The calculated values of cross-section of the reaction ^{169}Tm (p,n)^{169}Yb plotted in fig.2 show fair agreement with the EXFOR data. The level density option based calculations show better agreement with experimental data [5] up to 11MeV. The maximum production yield 157.43 mb was obtained at 9MeV energy with idmodel4.

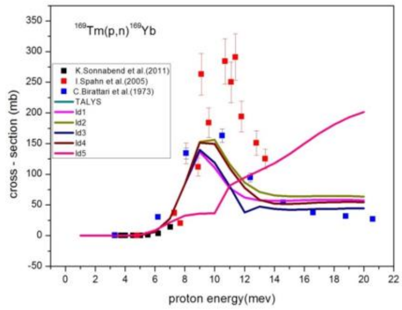

Fig.2: Calculated excitation function of reaction ^{169}Tm(p,n)^{169}Yb and comparison with experimental results.

The calculated excitation function of reaction ^{192}Os(p,n)^{192}Ir plotted in fig.3 reveals that calculated data using TALYS with the level density parameters are well matched with the experimental data. The optimum production yield (73.32 mb) of radioisotope ^{192}Ir found at energy 9 MeV. A good agreement of TALYS with level density model 1,2,3,4 and experimental data [6] found in the energy region 9-15 MeV.

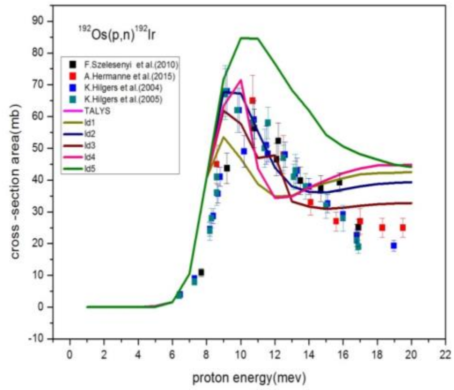

Fig. 3: Calculated excitation function of reaction ^{192}Os(p,n)^{192}Ir and comparison with experimental results.

Conclusion

It is seen from the figures that theoretical results obtained using TALYS 1.6 code are compatible with the experimental data from the literature. The present study also reveals that nuclear level density option which has been incorporated in this code recently is quite suitable in predicting of the excitation function of (p,n) reaction for the production of medical radioisotopes ^{64}Cu, ^{169}Yb and ^{192}Ir in the energy region threshold to 20MeV. Finally, it is concluded that the excitation function values calculated with TALYS 1.6 code for all above reactions are mostly in agreement with the experimental data.

References

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