Medical radioisotopes production: A comprehensive cross section study for the production of ^{64}Cu radioisotope via proton induced nuclear reaction on ^{nat}Ni

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Introduction

As a part of continuous program of systematic study of progress of nuclear reactions at low and intermediate energies we have analyzed the production of ^{64}Cu radioisotope via proton induced nuclear reaction on ^{nat}Ni over the energy range from 0 - 40 MeV and the consistency check of experimental data was carried out using the nuclear model codes EMPIRE - 3.2.3 - MALTA [1] and TALYS 1.6 [2]. The radioisotopes of copper have great potential for preparing metal - chelates for medical use. In particular the radionuclide ^{64}Cu is very well suited: it has appropriate half - life, a low $\beta+$ end - point energy of 0.65 MeV and half-life 12.7 h. The decay properties are almost ideal for imaging. The radionuclide ^{64}Cu ($T_{1/2}$ = 12.7 h) is an important non - standard positron emitter, suitable for combining PET imaging and targeted therapy.

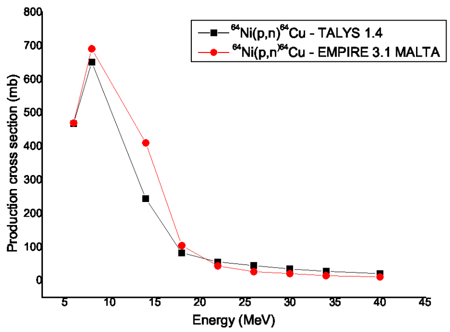

FIG. 1: Excitation function of the ^{64}Ni(p,n)^{64}Cu reaction compared with EMPIRE 3.2.3 - MALTA and TALYS 1.6 nuclear reaction model code.

1. Evaluation procedure and Nuclear model calculations

The normalized experimental data were compared with the results of nuclear model calculations using two codes, EMPIRE and TALYS. The nuclear reaction code system, EMPIRE 3.2.3 - MALTA, has been designed to perform nuclear reaction calculations over a wide range of energies and incident particles. The covered energy range is from resonance region (∼keV) to several hundreds of MeV, and the projectile could be any nucleon, ion (including heavy ion) or a photon. EMPIRE is equipped with a complex system of codes to describe all the important nuclear reaction mechanisms. The optical model and the direct reaction calculations were performed by the ECIS - 03 code. The optical model, discrete levels and deformation parameters were retrieved from the RIPL - 2 library. The direct channel calculations were performed by using the coupled channels model or the distorted wave Born approximation (DWBA) method. EMPIRE contains both the quantum mechanical (MSD/MSC) and classical models (DEGAS, PCROSS, HMS) to describe pre - equilibrium reactions. TALYS, a nuclear reaction software developed at NRG Petten and CEA Bruyres - le - Chtel, provides a continuous and smooth description of nuclear reactions over a wide energy and mass range. Nu-

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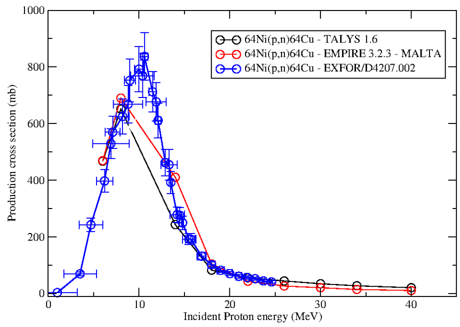

FIG. 2: Selected experimental data alongwith the results of calculations using the nuclear model codes EMPIRE AND TALYS for the ^{64}Ni(p,n)^{64}Cu reaction.

clear reactions induced by neutrons, protons, deuterons, tritons, helions, alphas and photons can be simulated in the 1 keV to 200 MeV energy range. TALYS contains a vast database for nuclear structure and model parameters, mostly based on the IAEA Reference Input Parameter Library. TALYS incorporates a number of nuclear models to analyze all the significant nuclear reaction mechanisms. The ECIS 06 code was used to perform the optical model and direct reaction calculations. The default optical model potentials (OMPs) of TALYS for neutrons and protons are from the local and global parametrizations by Koning and Delaroche, whereas OMPs for deuterons, tritons, helions and alpha particles are based on the folding approach. Depending on the structure of the nuclei, calculations for direct reactions can be performed by the coupled channel method, the distorted wave Born approximation (DWBA), the weak - coupling model, and a phenomenological model for the giant resonances description. In all the calculations the default options for the direct reactions were used. The compound nucleus was treated within the frame work of Hauser Feshbach model along with the width fluctuation correction model of Moldauer. The pre - equilibrium reaction calculations were performed by the exciton model. The model parameters were adjusted to get a better agreement between the experimental and calculated cross section values.

2. Results and discussion

The EMPIRE code calculations for the direct reactions were performed by the DWBA model with slight modification of the local optical model potential. The options of multi - step direct (MSD) and multi - step compound (MSC) were executed for pre - equilibrium emission of protons. For neutron and cluster emission in pre - equilibrium reactions the value of PCROSS was set as 1.5, and the single particle level density parameter (GTILNO) was multiplied by 0.7. The calculations by the TALYS code were invoked by the default optical model potential (OMP) for proton. However, to get a better agreement between the experimental and calculated cross sections some parameters were adjusted. The average effective matrix element was adjusted by setting M2constant = 0.6. The excitation function of the ^{64}Ni(p,n)^{64}Cu reaction compared with EMPIRE 3.2.3 - MALTA and TALYS 1.6 nuclear reaction model codes are shown in fig.1. Good agreement could be achieved between calculated and measured excitation functions by a careful choice of nuclear model parameters. In general, the model calculations did not validate the absolute values of experimental data, but were able to validate the consistency of different experiments in different energy ranges. Good experiments indirectly help to refine nuclear models, particularly in depicting the significance of various model parameters. Selected experimental data alongwith the results of calculations using the nuclear model codes EMPIRE AND TALYS for the ^{64}Ni(p,n)^{64}Cu reaction is shown in fig.2. The details will be presented.

References

[1] M. Herman, Empire 3.2.3 Malta, NEA Data Bank,(2012). http://www.nndc.bnl.gov/empire219

[2] A. J. Koning et. al., TALYS 1.6 - A nuclear reaction program (2011).