Production cross-sections of ^{56}Co radio nuclide from ^{56}Fe

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Introduction

Study of proton induced reaction cross sections is important for medical radioisotope production, ion beam analysis, validation of nuclear reaction models, shield design for nuclear facilities etc. [1,2]. Radio isotope ^{56}Co produced in ^{56}Fe(p,n) reaction is used as calibration source for ɔ-ray detectors. Stainless steel containing iron is a major component of the beam line in low and high energy accelerators and is a potential source of induced activity due to ^{56}Co in the case of any accidental exposure or otherwise[3].

In the present work, the production cross-section of ^{56}Co has been calculated for ^{56}Fe (p, n) ^{56}Co reaction for 1-50 MeV energy using statistical and pre-equilibrium (PEQ) nuclear reaction model codes. The computed excitation functions are compared with the available experimental data [4].

Model Codes Calculations

TALYS-1.8

In TALYS-1.8 [5] code, direct reactions are calculated using giant resonances. Two component exciton model estimates the PEQ particle emission and the angular distribution of these PEQ particles is determined using Kalbach systematics. Compound nuclear emission is calculated in the framework of Hauser-Feshbach formalism in competition to fission. In this work we have used numerical transition rates with energy dependent matrix element for exciton model (preeqmode=2), Fuôs pairing energy correction (pair model=1) and following level density options:

TALYS1:(ldmodel1)Constant temperature Fermi gas model
TALYS2:(ldmodel2)Backshifted Fermi gas model
TALYS3:(ldmodel3)Generalized Super fluid model

EMPIRE-3.2

Computations using EMPIRE-3.2 code [6] have been carried out with different PEQ models and the statistical Hauserï Feshbach theory to describe the compound nuclear emissions using different level density options:

EMPIRE1-3: Empire specific level densities (LEVDEN=0) have been used along with various pre-equilibrium models like PCROSS, PCROSS+HMS & MSC+MSD respectively.
Empire 4-6: Generalized super fluid model level densities (LEVDEN=1) have been used along with the above listed PEQ models combinations respectively.

Results and Discussion

Excitation functions of ^{56}Fe (p, n) ^{56}Co reaction are shown in figs. 1 and 2 using nuclear reaction codes EMPIRE & TALYS. From figure 1 it has been observed that EMPIRE calculation with cluster PEQ emission matches well with available experimental data for emission energies above 18 MeV. Pre-equilibrium models PCROSS along with Hybrid Monte Carlo Simulation show good agreement with available data whereas quantum mechanical Pre-equilibrium model MSC only reproduced shape of reported data. At energies below 10 MeV EMPIRE calculations could not reproduce the measured cross sections showing that compound nuclear emissions are not well predicted. The results from TALYS code reproduce the measured cross sections only above 20 MeV. The combination of exciton model numerical transition rates with energy dependent matrix element and Fuôs pairing energy correction agrees better with the experimental data as compared to other level density options.

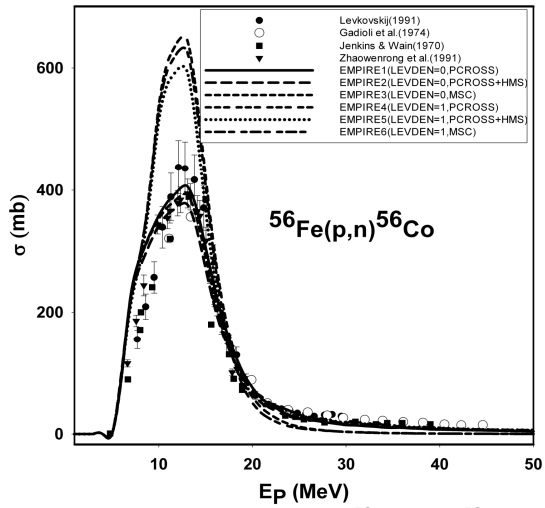

Fig. 1: Excitation function of ^{56}Fe (p, n) ^{56}Co with code EMPIRE

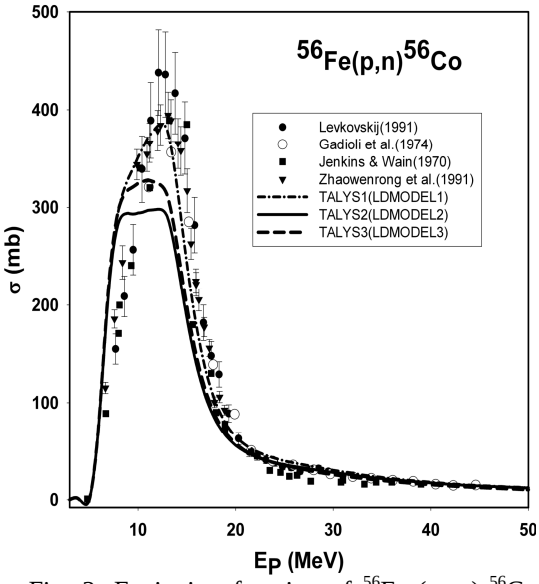

Fig. 2: Excitation function of ^{56}Fe (p, n) ^{56}Co with code TALYS

EMPIRE 2 & 5 show good fit with Jenkins *et al.* data above 18 MeV (P value-0.7 using reduced χ^2 test). EMPIRE5 shows good fit with Levkovskii data in the range 15 to 26.6 MeV (P value-0.98). Further analysis for all the isotopes are being carried out.

Conclusion

The computed results from EMPIRE with PCROSS and PCROSS+HMS PEQ options predict the measured data well above 18 MeV incident energy as compared to those using MSC. Though the reaction channel considered in this work involves neutron emission only, the analysis suggests that PEQ emission of clusters leading to other reaction channels has a strong bearing on the (p,n) cross section studied. Reduced χ^2 test also confirms the goodness of fit. Level density of the residual nucleus does not play important role in this emission energy range as the emissions are strongly influenced by PEQ reaction. TALYS calculations predict the PEQ emissions well only above 20 MeV emission energy.

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