Production cross-sections of ^{90}Nb radio nuclide from ^{90}Zr

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Introduction

The nuclear cross sections computed from model codes are significant even when experimental data are available. Zr plays a significant role both in nuclear technology and in medical application. Zr has low neutron cross-section, appropriate thermal conductivity and high mechanical resistance. These properties render the element and its alloys as suitable choices as construction material for nuclear reactors. Zr also produces some medically important radio isotopes through proton induced reactions which can be used to diagnose the tumor and in tumor therapy [1-2].

In the current work, the production cross-section of ^{90}Nb from ^{90}Zr (p, n) ^{90}Nb reaction has been calculated for the energy range 1-30 MeV using EMPIRE, TALYS and ALICE nuclear reaction model codes. The investigated results are compared with the available experimental data [3].

Model Codes Calculations

TALYS-1.9

TALYS-1.9 [4] code employs two component exciton model for pre-equilibrium (PEQ) particle emission. The Kalbach systematics is used for angular distribution of these PEQ particles. The direct reactions are computed using giant resonances. Compound nuclear emission is estimated in the framework of Hauser-Feshbach formalism. For the present work numerical transition rates with energy dependent matrix element for exciton model, Fu's pairing energy correction (pair model=1) and following level density options are used:

TALYS1: (ldmodel1) Constant temperature Fermi gas model

TALYS5: (ldmodel5) Microscopic parity dependent level density model

EMPIRE-3.2

The calculations using EMPIRE-3.2 [5] code have been performed with various pre-compound models. Hauser–Feshbach theory is used to calculate the compound nuclear emissions along with various models of level densities:

EMPIRE1-3: (LEVDEN=0) Empire specific level densities used along with various pre-equilibrium models like PCROSS, PCROSS+HMS & MSC respectively.

Empire 4-6: (LEVDEN=2) Microscopic parity dependent level density along with the PCROSS, PCROSS+HMS & MSC pre-equilibrium models respectively.

ALICE-91

In ALICE-91 [6] code, the Weisskopf–Ewing formalism is used for equilibrium calculations while hybrid/geometry dependent hybrid model considered for pre-equilibrium cross-sections. The following input options of the code are used as:

ALICE1-4: Fermi Gas level density with various options of pairing term (i.e., no pairing term in masses, pairing term in masses applied back shifted, pairing term in masses applied back shifted with shell correction & normal pairing shift in masses respectively.

ALICE5: Kataria Ramamurthy formula for level density with no pairing term in masses.

Results and Discussion

The excitation functions computed by the theoretical model codes EMPIRE, ALICE and TALYS for the ^{90}Zr(p,n)^{90}Nb reaction are plotted in figures 1 and 2 and compared with the avaialble data. EMPIRE computed results using EMPIRE specific and parity dependent level density reproduce shape of measured excitation functions [3] but over predict the absolute values in Levkovskii [3] and Busse *et al.* [3] between

15 MeV to 23 MeV. All ALICE calculations give good agreement with Busse *et al.* [3] and Levkovskii [3] data up to 18 MeV and above 25 MeV within experimental error. TALYS 5

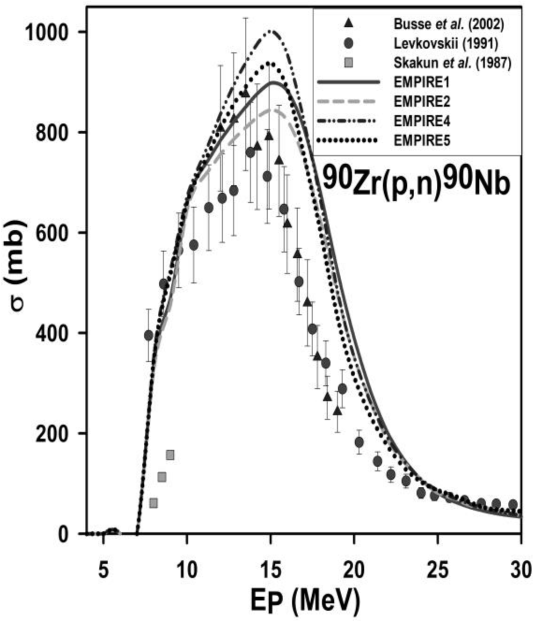

Fig. 1: Excitation function of ^{90}Zr (p, n) ^{90}Nb with code EMPIRE

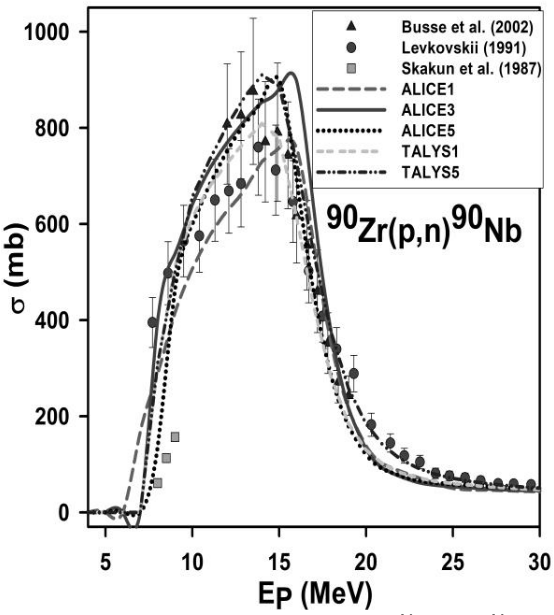

Fig. 2: Excitation function of ^{90}Zr(p,n)^{90}Nb with code ALICE and TALYS

results are in fair agreement with reported data. The results of TALYS1 are also consistent with measured data up to incident energy 18 MeV. Formation of compound nucleus is well predicted by ALICE and TALYS results.

The computed results from EMPIRE with PCROSS and PCROSS+HMS PEQ options reproduce the shape of measured data well. The findings suggest that PEQ emissions are important in the energy range considered. Overprediction of measured data by model calculations suggests that multiple- or cluster PEQ emission may have a strong bearing on cross-section studied of (p,n) reaction. TALYS 5 calculations predict the PEQ emissions well above 18 MeV energy range. ALICE results predict well the reported experimental data within strengthening the above-mentioned conjecture.

Conclusion

The hybrid model PEQ + evaporation predicts the ^{90}Zr(p,n)^{90}Nb excitation function fairly well in the energy range 5-30 MeV. The compound evaporation dominates upto 10 MeV.

Acknowledgement

The Financial assistance provided by DAE-BRNS, BARC, Mumbai is thankfully acknowledged by giving major research project (Sanction No. 2011/36/10-BRNS/0494).

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