Excitation functions for the production of radio nuclides by proton irradiation of Ge-76

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Introduction

Radioisotopes of arsenic are formed via many reactions. ^{76}As is used in the treatment of certain malignant skin cancer. A jacket of ^{75}As, irradiated by the intense high-energy neutron flux, would transmute into the radioactive isotope ^{76}As with a half-life of 1.0778 days and produce approximately 1.13 MeV gamma radiation. Radioisotope of As is also used as a radiotracer to determine As transport in soil. For optimal use of radioisotopes of As the production cross section of different radioisotopes need be known with good accuracy.

In the present work, the production cross-section of arsenic radioisotopes have been calculated for ^{76}Ge (p, n) ^{76}As reactions for 1-50 MeV energy using statistical and pre-equilibrium (PEQ) nuclear reaction model codes and compared with the reported measured data [1].

Model Codes Calculations

TALYS-1.2

In TALYS-1.2 [2] 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.

ALICE-91

ALICE-91 code [3] calculates PEQ cross-sections using hybrid/geometry dependent hybrid model and evaporation through Weisskopf–Ewing formalism. We have used the following input options of the code:

ALICE1-4: Using Fermi Gas level density along with different pairing term options (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.
ALICE5-8: Using Kataria Ramamurthy formula for level density with different pairing term options as listed above.

EMPIRE-3.1

Computations using EMPIRE-3.1 code [4] have been carried out with different PEQ models and the statistical Hauser–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 ^{76}Ge (p, n) ^{76}As reaction is shown in figs. 1 & 2. From perusal of these figs., it has been observed that up to 12 MeV the computed excitation functions using the three codes with the options chosen show fairly good agreement with each other. The results of computation with TALYS code using the combination of Exciton model numerical transition rates with energy dependent matrix element and Fu's pairing energy correction reasonably match with experimental data. The results of ALICE1using Fermi gas level density with no pairing term in masses ALICE2using Fermi gas level density with invoking pairing term in masses applied back shifted and ALICE4 using Fermi gas level density with normal pairing shift in mass shows good agreement with available experimental data .

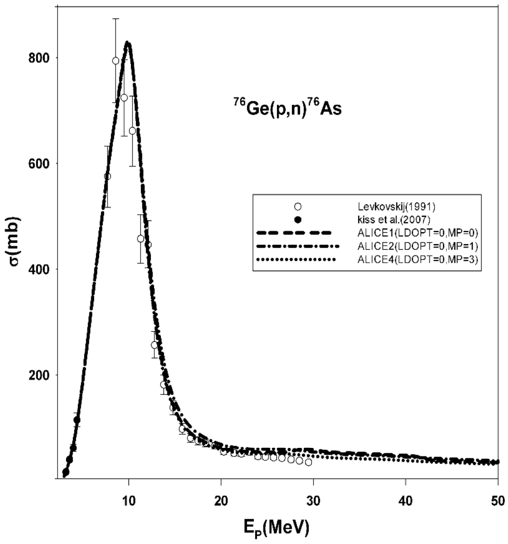

Fig. 1: Excitation function of ^{76}Ge (p, n) ^{76}As

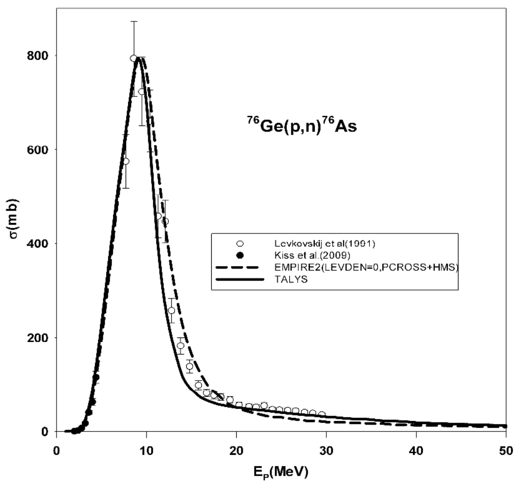

Fig. 2: Excitation function of ^{76}Ge (p, n) ^{76}As

From these figs. we see that measured excitation functions are well reproduced by the EMPIRE calculations with PCROSS + HMS PEQ models along with EMPIRE specific level density option. The χ^2 test shows that for ^{76}Ge (p, n) ^{76}As reaction ALICE1,ALICE2 ALICE4, TALYS & EMPIRE2 give good fit with the measured data of Kiss *et al.*(2007).

Further analysis for all the isotopes are being carried out.

Conclusion

The results of ALICE code predict that the Fermi gas level density is the best option to reproduce the measured data as compared to those using Kataria Ramamurthy formula for level density. The EMPIRE code using the combination of EMPIRE specific level density (i.e. Enhanced Global Super-fluid Model) with PCROSS + HMS PEQ options give fairly good fit for ^{76}As. The neutron emission is governed by the HMS PEQ model in this reaction. Thus we can conclude that there is a contribution from pre-equilibrium emission. The level density option chosen here works best for nucleon induced reactions in the energy range investigated. The χ^2 test also confirms the goodness of the fit. The calculations based on standard nuclear reaction models using well defined and established parameters will help in assessing the relative accuracy of the reported measurements and checking of validity of various parameters of the nuclear model codes.

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