Excitation functions for the production of radio nuclides by neutron irradiation of Tungsten

Sneh Lata Goyal[1,*], P. K. Saran[1], Maitreyee Nandy[2] and P. K. Sarkar[3]
[1]Deptt. of Applied Physics, Guru Jambheshwar University of Sci. & Tech., Hisar-125001, Haryana, INDIA
[2] Saha Institute of Nuclear Physics, Kolkata – 700064, INDIA
[3] Manipal Centre for Natural Sciences, Manipal University, Manipal-576104, INDIA

* Email: goyalsneh@yahoo.com

Introduction

Tungsten is a potential structural material in fusion technology. The use of evaluated neutron cross section data for tungsten in nuclear criticality safety calculations exhibits deficiencies [1]. The neutron induced cross sections of tungsten isotopes are not only used in numerous nuclear applications but are also of interest in nuclear astrophysics, where they determine the abundance in the slow neutron capture process.

In the present work we have calculated the excitation functions of ^{186}W (n, 2n) ^{185}W, ^{186}W (n, p) ^{186}Ta, ^{184}W (n, p) ^{184}Ta, ^{182}W (n, 2n) ^{181}W and ^{182}W (n, p) ^{182}Ta reactions for 1-20 MeV energy using statistical and pre-equilibrium (PEQ) nuclear reaction model codes. Comparison of the computed excitation functions with the reported measured data [5-11] and ENDF Files [12] have been shown in the figs1 &2.

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. Here in the present work, different PEQ reaction models have been used along with different pairing energy options.

ALICE-91

ALICE-91 code [3] calculates PEQ cross-sections using hybrid model and evaporation through Weisskopf–Ewing formalism. The geometry dependent hybrid (GDH) model is the modified version of hybrid model to include the effect of diffuse nuclear surface. In the present work we have used GDH model with Fermi gas level density and pairing term in masses to calculate the excitation functions.

EMPIRE-3.1

The EMPIRE-3.1 code [4], accounts for the major nuclear reaction mechanisms direct, PEQ and compound nuclear reactions along with fission. With EMPIRE-3.1 code computations have been carried out with different PEQ models like PCROSS, multistep direct (MSD), multistep compound (MSC) and hybrid Monte-Carlo simulation (HMS) approach and the statistical Hauser–Feshbach theory to describe the compound nuclear emissions using different level density options.

Results and Discussion

Excitation functions of ^{186}W (n, 2n) ^{185}W and ^{182}W (n, 2n) ^{181}W, when computed with TALYS code using the combination of (a) Exciton model numerical transition rates with energy dependent matrix element and Fu's pairing energy correction (TALYS1) or (b) Exciton model, numerical transition rates with optical model for collision probability and compound nucleus pairing energy correction (TALYS2) reasonably match with experimental data [5-8] within 5-20% accuracy within experimental error. The excitations functions of ^{186}W (n, 2n) ^{185}W and ^{182}W (n, 2n) ^{181}W obtained from ALICE code using Fermi Gas level density and pairing term in masses shows agreement with experimental data within 10-15%. Empire code calculations for ^{186}W (n, 2n) ^{185}W cross sections using Empire specific level densities with MSC+MSD PEQ models (EMPIRE1) give very good agreement with the experimental data available. PCROSS and HMS PEQ models along with different level density options reproduce excitation function with reasonable agreement with the experimental data.

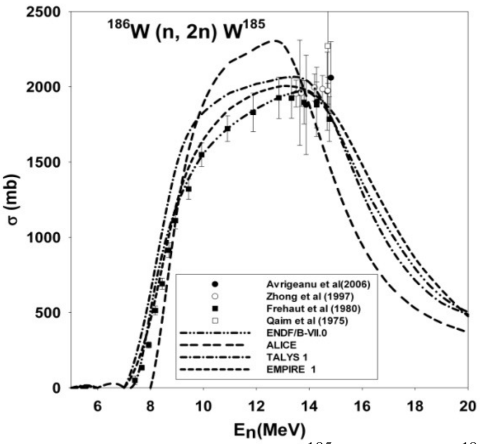

Fig. 1: Excitation function of ^{185}W from n + ^{186}W

TALYS1 calculation for ^{186}W (n, p) ^{186}Ta, ^{184}W (n, p) ^{184}Ta and ^{182}W (n, p) ^{182}Ta reactions shows good agreement with the measured data [5,8-11]. Empire code calculation for ^{186}W (n, p) ^{186}Ta, ^{184}W (n, p) ^{184}Ta and ^{182}W (n, p) ^{182}Ta reactions the combination of Empire specific or Generalized superfluid model level densities with HMS + PCROSS PEQ models (EMPIRE2 and EMPIRE3, respectively) give fair matching with experimental data. The χ^2 test shows that for ^{186}W (n, 2n) ^{185}W EMPIRE1 & TALYS1 give better agreement with measured data while for ^{182}W (n, 2n) ^{181}W EMPIRE3 and TALYS1 are closer. For (n, p) reactions considered the χ^2 test shows that EMPIRE2 and TALYS1give good fit. Further analysis for all the isotopes are being carried out.

Conclusion

The EMPIRE code with the combination of PCROSS and HMS shows good agreement in which multiple PEQ emission take place. The proton emission is governed by the HMS PEQ model in ^{186}W (n, p) ^{186}Ta reaction. TALYS is also considering the multiple PEQ emission. Thus here we can conclude that multi PEQ emission plays an important role. The χ^2 test also confirms the goodness of the fit. The main pur-

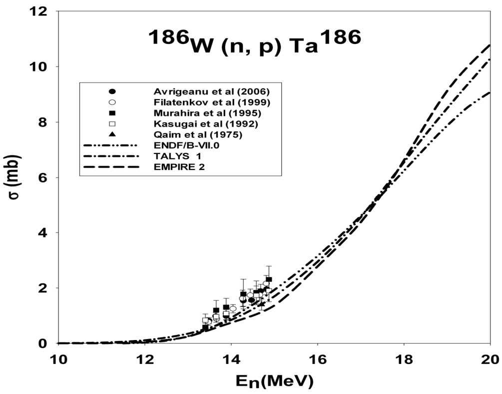

Fig. 2: Excitation function of ^{186}Ta from n + ^{186}W

pose of such comparison is to obtain cross section data for production of useful and undesirable isotopes and to test the reliability of nuclear reaction models.

Acknowledgement:

Financial support from DAE-BRNS, BARC, Mumbai by giving major research project is thankfully acknowledged.

References

[1] C Lampoudis, S Kopecky, P Schillebeeckx, *et al*, J. Kor Phys. Soc.**59**, p 1860 (2011).
[2] A J Koning S Hilaire and M C Duijvestjjn, TALYS1.2 A Nuclear Reaction Program, USER MANUAL" (December 22, 2009).
[3] M. Blann, LLNL Report UCID **19614**, (1984).
[4] M Herman, *et al*, Nucl. Data Sheets **108**, 2655 (2077).
[5] V.Avrigeanu, *et al*, Nucl. Phys. A**765**,1 (2006)
[6] K. X. Zhong, *et al* , Comm. Nucl. Data Prog. **17**, 9 (1997)
[7] J.Frehaut, *et al*, U.S. report No.**84(1)**, 399 (1980) Exfor Subent no.20416053
[8] S.M.Qaim, C.Graca, Nucl. Phys. A **242**, 317 (1975)
[9] A.A.Filatenkov, *et al*, Leningrad Reports No.**252** (1999) Exfor Subent no. 41240106
[10] S.Murahira, *et al*, Japanese report I.N.D.C. No.**175/U**, 171(1995)
[11] Y.Kasugai, *et al*, JAERI-M Reports No. **93, 046**, 277 (1992)
[12] Evaluated Nuclear Data File (ENDF) Database version of June 21, 2013.