Study of neutron induced reactions using EMPIRE-3 and TALYS

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Introduction

Accurate and reliable nuclear reaction data are very important for purposes of fission and fusion reactor design, nuclear fuel cycle and for a large variety of "non-energy" scientific applications. Nuclear data are generated mostly by nuclear physics experiments and also by nuclear theory. Nuclear data have a wide-spread use in nuclear science and technology, with neutron induced reaction data playing a prominent role. The most important applications are as input to the design calculations of nuclear fission reactors, nuclear medicine, nucleosynthesis, non-proliferation, space exploration etc. In any application of nuclear data there is a genuine interest to use the best information that are available. The results of different nuclear physics measurements usually do not agree with each other. In addition, measurement simply not feasible in some cases. Therefore Nuclear theory/reaction model calculations play important role in such cases as well as for interpolation and extrapolation of the data wherever experimental information is not available.

We have a continued program on n-induced reaction cross section measurement and nuclear model calculations on various nuclei that have usages in nuclear technology applications. In the present communication we report the EMPIRE and TALYS calculations for several systems over a broad range of neutron energies and a detailed study of cross section dependence on various choices of model and parameters.

EMPIRE - 3.2(Malta) and TALYS-1.8 statistical model calculations:

Calculations for reactions ^{92,96}Mo (n,p), ^{100}Mo (n,2n) and ^{208}Pb (n,p) have been performed in the energy range from threshold to up to 16 MeV. In the EMPIRE calculations standard Hauser-Feshbach formalism was applied for compound nucleus decay and the EMPIRE specific level density model was used which uses the super fluid BCS model below the critical energy (U_{crt}) and Fermi gas level density model above the critical energy. For calculating pre-equilibrium effects in the emission spectra, the exciton model DEGAS code was used. Direct reaction contributions were calculated using the ECIS06 code with OM potentials take from Ref.[1] and Ref.[2] for n and p respectively. The required input parameters to the calculations were taken from in built RIPL-3 library. A consistency check as detailed in Ref.[3], for each of the reactions studied here, was done to find whether the discrete level schemes for the involved nuclei are consistent with the level density parameterization.

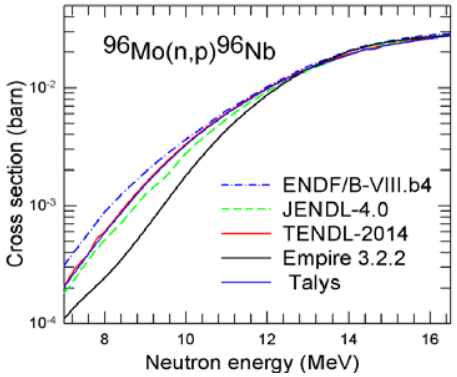

Fig.1 Excitation function for ^{96}Mo(n,p): Comparison of EMPIRE with TALYS and Nuclear data evaluations.

The EMPIRE results are shown in Figs. 1-4 and are compared with TALYS calculations as well as with different nuclear data evaluations. The TALYS calculations were performed with default set of input parameters in which exciton

model for pre-equilibrium emission, back shifted Fermi gas model for level density parameter and global OM potential[1] was used. The agreement between EMPIRE and TALYS calculations in general is good, however, in some reactions a significant discrepancy is observed especially at higher energies.

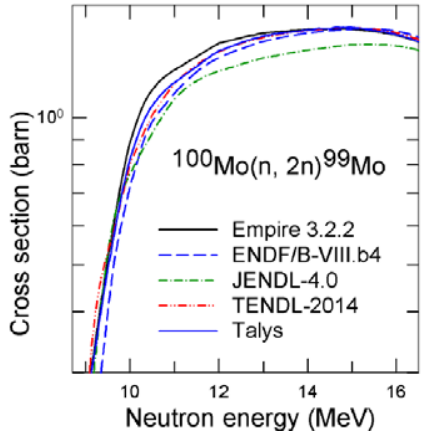

Fig.2 Excitation function for ^{100}Mo(n,2n): Comparison of EMPIRE with TALYS and nuclear data evaluations.

A detailed study of cross section dependence on various reaction model choices and parameter dependence are performed at E_n ~ 14 MeV. Cross sections with different choices of OM potentials are observed to vary within 10% in these reactions except for ^{208}Pb(n,p) where the variation is as large as ~35%.

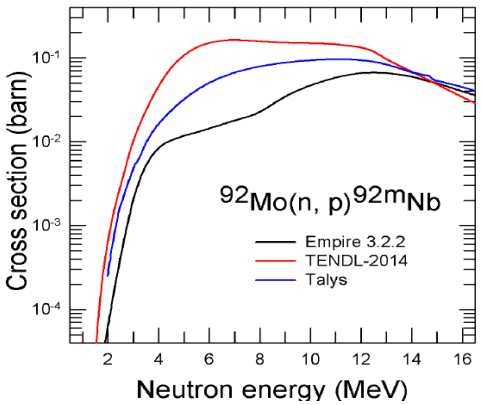

Fig.3 Excitation function for ^{92}Mo(n,p): Comparison of EMPIRE with TALYS and Nuclear data evaluations.

The calculations done with (levden=0, pcross =1.5, MSD=0, MSC=0) and without (levden=0, pcross=0, MSD=0, MSC=0) pre-equilibrium options indicate inclusion of pre-equilibrium processes changes the cross section by about 5%, 20%, 30% and 33% for reactions ^{100}Mo(n,2n), ^{208}Pb(n,p), ^{92}Mo(n,p) and ^{96}Mo(n,p) respectively. For level density parameter (atilno factor in EMPIRE), cross sections are observed to be very sensitive on the choice of atilno factor and varies from reactions to reactions. The atilno factor was decided that gives best agreement with measured data around 14 MeV [4].

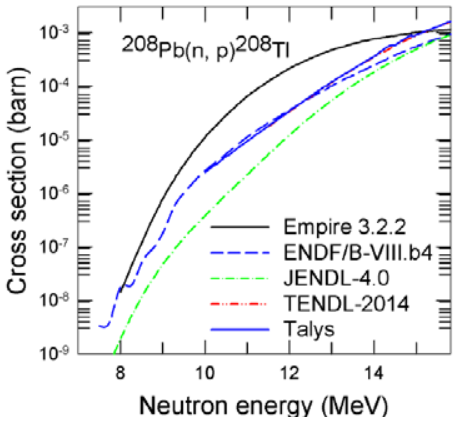

Fig.4 Excitation function for ^{208}Pb(n,p): Comparison of EMPIRE with TALYS and nuclear data evaluations.

Acknowledgement

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References

[1] A.J.Koning et al., NPA 713, 231 (2003)
[2] B.Morillon et al., PRC 76, 044601 (2007)
[3] M.Bhike, B.J.Roy et al., Nucl. Sci. Eng. 170, 44, (2012).
[4] B.J.Roy, A.Gandhi, Y. Sawant, A.Saxena, B. K.Nayak, A.Tyagi, S.D.Dhole, V. N. Bhoraskar, Measurement of ^{67}Zn, ^{92,96}Mo, ^{208}Pb(n, p) and ^{70}Zn,^{100}Mo(n, 2n) Reaction Cross Sections at E_n ~ 14 MeV, Nucl. Sci. Eng. (being submitted).