Influence of isospin dependent level density parameter on neutron induced reaction cross section

Sangeeta[1],* B. K. Nayak[2],† A. Saxena[2], S. V. Suryanarayan[2], G. Mohanto[2], and B. Pandey[3]
[1]*School of Physics and Materials Science, Thapar University, Patiala-147004, Punjab (INDIA)*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[3]*Physics Department, G. B. Pant University, Pantnagar, Uttrakhand - 200001, INDIA*

Introduction

Neutron induced reactions cross section data are important for nuclear technology research and development, medical applications and for the transmutation of nuclear waste. The structural materials of a reactor is stainless steel with Cr, Fe and Ni as main constituents. The main effect of structural materials on reactor neutron balance consists in absorption of neutron via (n,γ), (n,2n), (n,p) and (n,α) reactions. Thus the precise knowledge of cross sections is quite essential in the reactor technology [1]. Intriguingly, nuclear level densities are indispensable in the study of nuclear reaction cross sections and nuclear reaction rates [2]. There has been much progress in the development of nuclear reaction codes. The variety of input parameters helps to describe existing experimental data more precisely. Nowadays the major interest in studying the isospin dependence of the level density arises from the need to find a description more suited for the decay of very exotic systems like those produced by radioactive beams. Recently, Moro et. al [3] studied the evaporative decay of the compound nucleus ^{139}Eu produced by the 180 MeV ^{32}S+^{107}Ag reaction and tested the empirical isospin expressions of the level density using computer code LALITA. The (N-Z) prescription seems to better describe the experimental data. Therefore, in the present work, a quantitative analysis have been carried out for neutron induced reactions cross section of ^{56}Fe using EMPIRE code including the isospin dependence of asymptotic level density parameter and compared the results with experimental data.

TABLE I: Expressions for the asymptotic level density parameter ã.

Expressions for ã	Parameters
NoIso(EGSM): $\alpha A + \beta A^{2/3}$	α=0.103,β=-0.105
NoIso(GSM): αA	α=0.0748
N-Z: $\alpha A + exp[\beta(N-Z)^2]$	α=0.1062,β=0.00051
Z-Z$_o$: $\alpha A + exp[\gamma(Z-Z_o)^2]$ $Z_o = (0.5042A)/(1+0.0073A^{2/3})$	α=0.1068,γ=0.0389

Calculations and results

We used the EMPIRE computer code [4], which is the most sophisticated publicly available code designed for reaction cross section calculations. The EMPIRE calculations includes all the major reaction mechanisms like, fusion, direct reaction, fission, pre-equilibrium emission. The optical model parameters are taken from Reference Input Parameter Library (RIPL-2) [5] library. For the transmission coefficients of outgoing neutrons and protons, we employed the OMP parameter of Koning et al. from [6], whereas the OMP parameter of V. Avrigeanu et al. from Ref. [7] were utilized for the transmission coefficient of the outgoing α particles. Pre-equilibrium emission was included using the Monte Carlo Hybrid (DDHMS) pre-equilibrium model. We have compared the calculated results of cross

*Electronic address: sangeeta.ar003@gmail.com
†Electronic address: bknayak@barc.gov.in

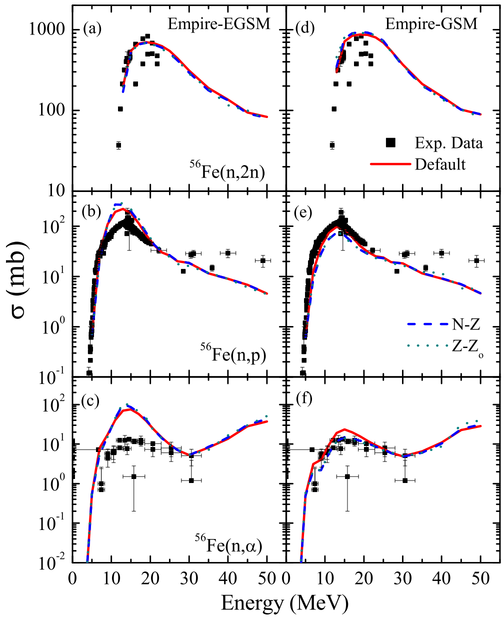

FIG. 1: Experimental and calculated cross sections of the reaction $^{56}Fe(n, 2n)$, $^{56}Fe(n, p)$ and $^{56}Fe(n, \alpha)$.

section for (n,2n), (n,p) and (n,α) for $^{50-52}$Cr, $^{54-56}$Fe and ^{58}Ni using four different level density parameterizations: EGSM, GSM, GCM as well as HFBM, with the experimental cross sections, taken from the IAEA reaction data web site EXFOR [8] (figure not shown here). Our analysis reveals that, Empire specific (or EGSM model) along with default potential parameters of EMPIRE sufficiently explains the experimental data of neutron induced reaction cross section for almost all reactions other than ^{56}Fe, which is most stable and abundance isotope of Fe used in reactors. In Fig. 1 we present results on statistical model calculations using EMPIRE code for (n,2n), (n,p) and (n,α) reactions of ^{56}Fe with EGSM model (left panels) as well as with GSM model (right panels) and compared with experimental data with the predictions of different level density prescriptions: i) isospin independence, ii) dependence from (N-Z) and iii) dependence from (Z-Z$_o$) as proposed by Al-Quraishi et al. [9] and described in Table I. The solid lines in the figure represents the calculations with isospin independent form of asymptotic level density parameter $\tilde{a}$. Whereas, the dashed and dotted lines represents the isospin dependent for of $\tilde{a}$ through (N-Z) and (Z-Z$_o$) respectively.

Conclusion

As shown in Fig.1, for the (n,2n) channel, isospin dependent forms of $\tilde{a}$ does not make much in the value of the cross section. For (n,p) and (n,α) channels, there are slight increase in cross sections with EGSM; however, decrease with GSM, around E = 10-16 MeV/nucleon. Moreover, the isospin dependence of $\tilde{a}$ through (N-Z) as well as (Z-Z$_o$) improves the agreement between experimental data and theoretical predictions of EMPIRE code only for (n,α) channel. Further detailed work in this direction are under consideration.

Acknowledgement

The financial support from Department of Science and Technology (grant no. DST/INSPIRE/03/2014/000234), Government of INDIA, New Delhi is gratefully acknowledged.

References

[1] M. Chadwick *et al.*, Nucl. Data Sheets **107**, 2931 (2006).
[2] T. Rauscher, F.-K. Thielemann and K.-L. Kratz, Phys. Rev. C **56**, 1613 (1997).
[3] R. Moro *et al.*, Eur. Phys. J. A **48**, 159 (2012).
[4] M. Herman *et al.*, Nucl. Data Sheets **108**,2655 (2007).
[5] R. Capote *et al.*, Nucl. Data Sheets **110** 3107 (2009), "http://www-nds.iaea.org/ripl2/"
[6] A. J. Koning, J. P. Delaroche, Nucl. Phys. A **713**, 231 (2003).
[7] V. Avrigeanu ,P. E. Hodgson and M. Avrigeanu, Report OUNP-94-02 (1994); Phys. Rev. C **49**, 2136 (1994).
[8] Experimental Nuclear Reaction Data, "http://www-nds.iaea.org/exfor"
[9] S.I. Al-Quraishi *et al.*, Phys. Rev. C **67**, 015803 (2003).