International Journal of Scientific Research in Physics and Applied Sciences
Research Paper
Vol.6, Issue.5, pp.125-133, October (2018)
E-ISSN: 2348-3423

(n, α) Reaction Cross-section of Stable isotopes of Platinum and Osmium for Fusion Reactor Technology

Amit Badola[1*], S.K. Singhal[2], Manoj Bhatnagar[1]

[1] Department of Physics, DIT University, Dehradun, Uttarakhand-248009, India
[2] Faculty of Science & Technology, ICFAI University, Dehradun, Uttarakhand- 247167, India

**Corresponding Author:* amitbadola555@gmail.com, *Tel.: +91-9012752001*

Available online at: www.isroset.org

Received:18/Jun/2018, Accepted:27/May/2018, Online: 31/Oct/2018

Abstract— The neutron induced reaction cross section of eleven stable isotopes of Platinum and Osmium i.e. ^{192}Pt(n,α)^{189}Os, ^{194}Pt(n,α)^{191}Os, ^{195}Pt(n,α)^{192}Os, ^{196}Pt(n,α)^{193}Os, ^{198}Pt(n,α)^{195}Os ^{184}Os(n,α)^{181}W, ^{187}Os(n,α)^{184}W, ^{188}Os(n,α)^{185}W, ^{189}Os(n,α)^{186}W, ^{190}Os(n,α)^{187}W and ^{192}Os(n,α)^{189}W have been calculated by using software TALYS 1.4 in the energy range between 13MeV to 15MeV. The present situation of (n, α) reaction cross section data for the energy region just below and above the 14MeV threshold region is important for reactor technology but as of now it is still extremely little and discrepant. Thus, the precise cross- sections of all kinds of nuclear reactions are very important and necessary. The result obtained has been compared with several experimental values taken from EXFOR data file and the updated evaluated data file of ROSFOND-2010, JEFF-3.2 and JENDL-4.0.

Keywords— Isotopes; Cross-sections; TALYS-1.4

I. Introduction

The neutron-induced reaction cross section i.e. (n,p), (n,α), (n,n) etc. data is essential for designing fusion and fission reactors, neutron dosimeters, nuclear transmutation rate calculation and also for developing advanced nuclear theory. The core and walls of the reactor are mostly available at 14MeV and therefore analysis of (n, α) reaction cross-section is extremely essential around this energy region. (n, α) reaction cross section data also improves the model-based calculations to explain the observed systematic as well as the isospin and isotopic requirement. Markovskij [1] and Cheng [2] estimates induced radioactivity, radiation damage etc. from reaction cross-section data. Similarly, Kao [3],

Eapen [4] and Vanska [5] concludes that they are useful for various studies like transfer of angular momentum, spin-dependence of nuclear level density, refinements in gamma transition theories and testing of theoretical nuclear models**.** In few reactions measured data of activation cross sections at little energy are available but complete excitation function of the reactions is necessary for the development of fusion reactors. Therefore, theoretical investigation is needed to support and extend the experimental cross-sections data for entire incident neutron energies. The selection of reliable data is still difficult even after the published experimental values of cross-sections as in many cases they show unexpected deviations in the values of cross-section with energy.

Keeping this in view we have taken experimental data along with various data libraries which are then compared with the nuclear model code TALYS-1.4 [6] developed by Koning et al. in 2013. TALYS calculates cross-sections for all reaction channels. In the present work (n,α) reactions cross-sections have been calculated for stable isotopes of heavy transition elements like Platinum, Osmium and its isotopes from 13- 15MeV of incident neutron energy by using nuclear reaction model code TALYS-1.4 [6] and compared these with the existing experimental data values taken from EXFOR [7] data library file as well as evaluated data files by ROSFOND-2010 [8], JEFF-3.2 [9] and JENDL-4.0 [10]. The pre-equilibrium emission plays an important role in determining the (n, α) reactions cross-section and therefore we have studied the compound nucleus and pre-equilibrium components on these reactions. The main aim of this work is to check the predictive power of TALYS-1.4 [6] to calculate the unknown cross-sections for some important nuclei reactions. This aim was accomplished by cross checking of used parameters by the available experimental data, systematic studies and the trend of calculated results for that particular range of incident energies.

II. Methodology

TALYS code can be executed manually using script. If we have created our own working directory with an input file named e.g. input, then a TALYS calculation can be easily started with talys<input>output. The structure of mandatory input file for the calculations here are; neutron is the projectile used, element is Platinum, Osmium and their isotopes, Energy is the incident energy of neutron in MeV which is taken from 13MeV to 15MeV. Out of the various given modes in TALYS, we used Exciton model in Preeqmode 2. We have also used Idmodel 2 which is Fermi back shifted model. Before running the code, we have optimized the input file. In TALYS-1.4, we have used Idmodel5 which accounts for the microscopic nuclear level densities from Hilaire's table [11] and preeqmode 2 which is an exciton model [12]. The computed cross-sections together with the experimental data taken from EXFOR [7] data library and data files namely ROSFOND-2010 [8], JEFF-3.2 [9] and JENDL-4.0 [10] file as shown in figures from Fig.1 to Fig.11

III. Results and Discussion

The results obtained by using TALYS 1.4 and various libraries with experimental data are as follows

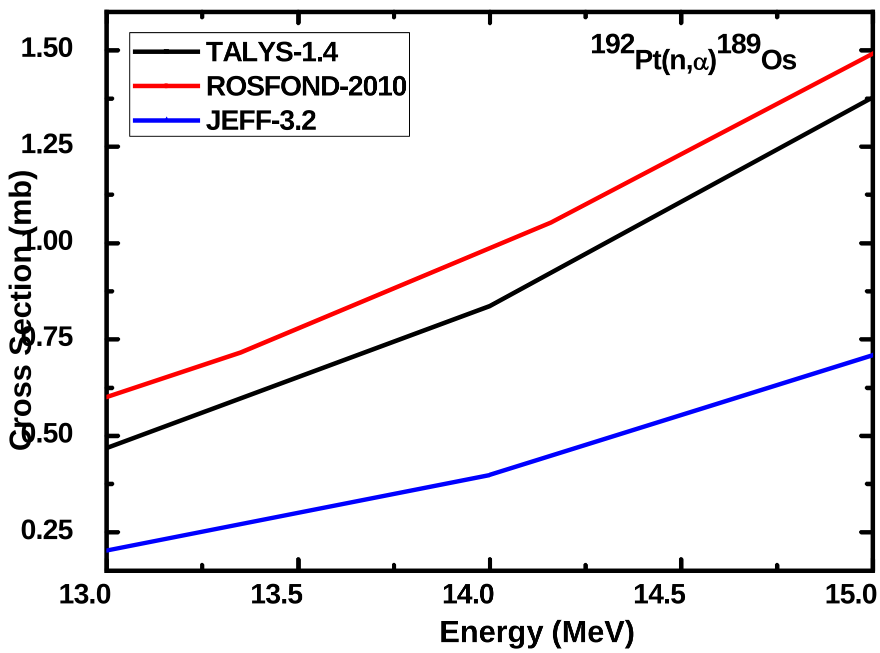

Fig1. Excitation function of the ^{192}Pt(n,α)^{189}Os reaction

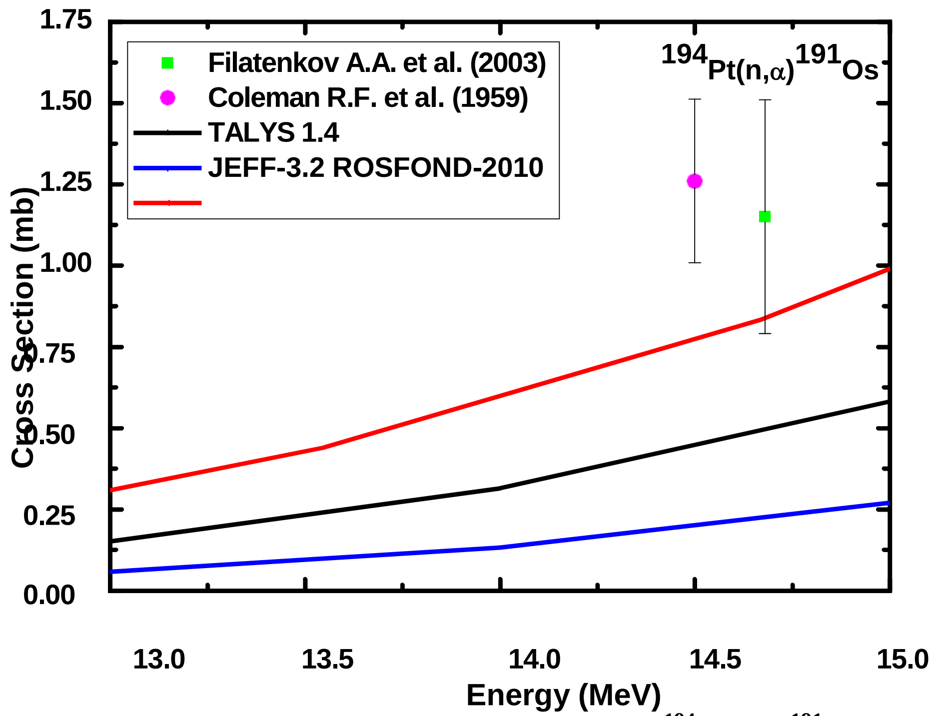

Fig2. Excitation function of the $^{194}Pt(n,\alpha)^{191}Os$ reaction

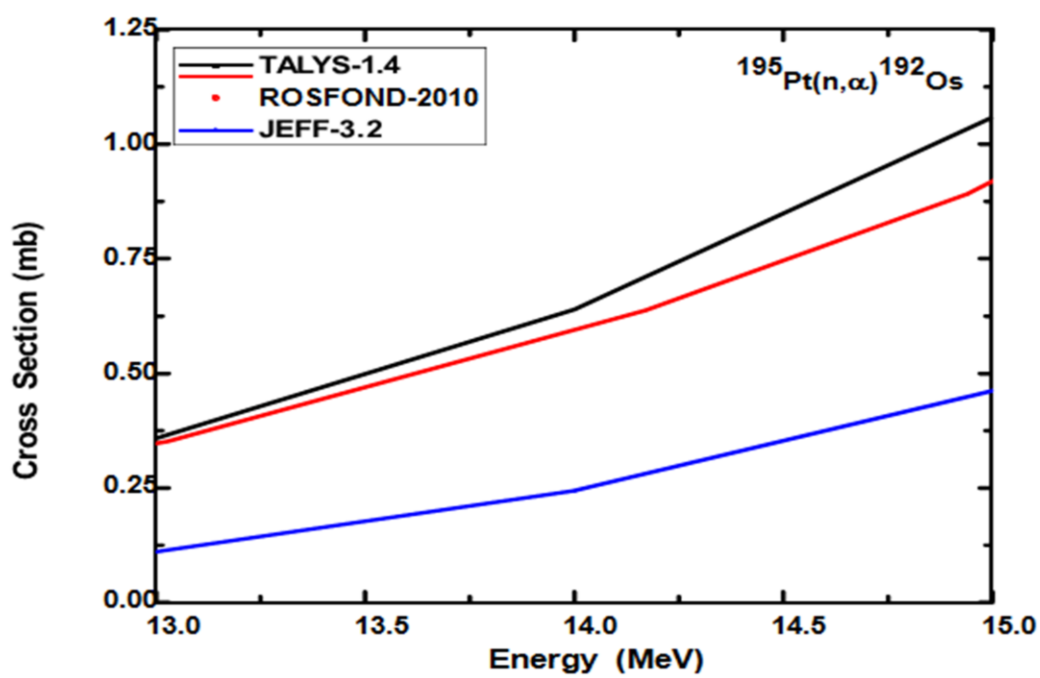

Fig3. Excitation function of the $^{195}Pt\ (n,\alpha)\ ^{192}Os$ reaction

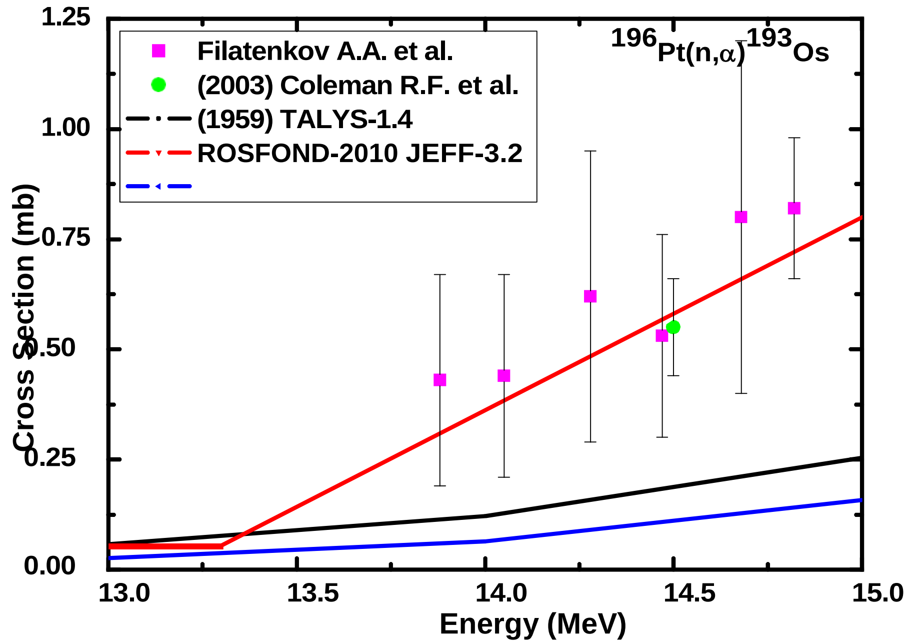

Fig4. Excitation function of the ^{196}Pt(n,α)^{193}Os reaction

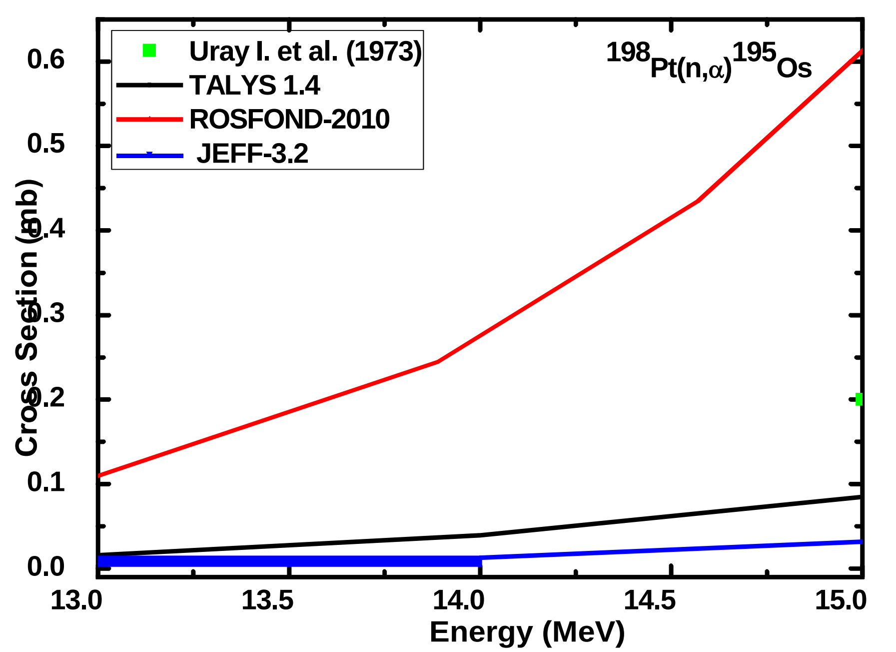

Fig5. Excitation function of the ^{198}Pt(n,α)^{195}Os reaction

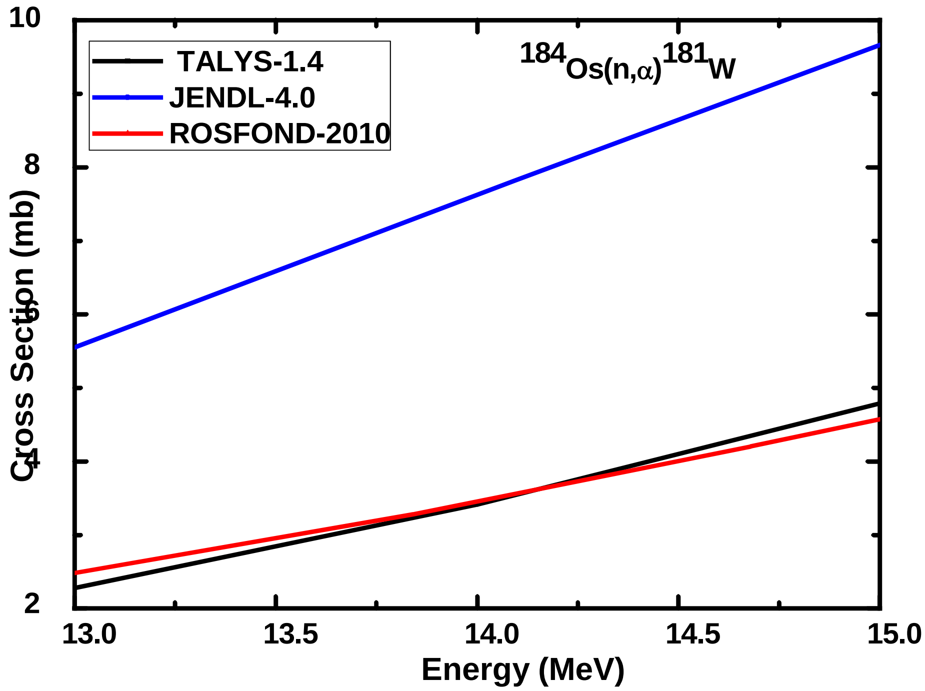

Fig6. Excitation function of the $^{184}Os(n,\alpha)^{181}W$ reaction

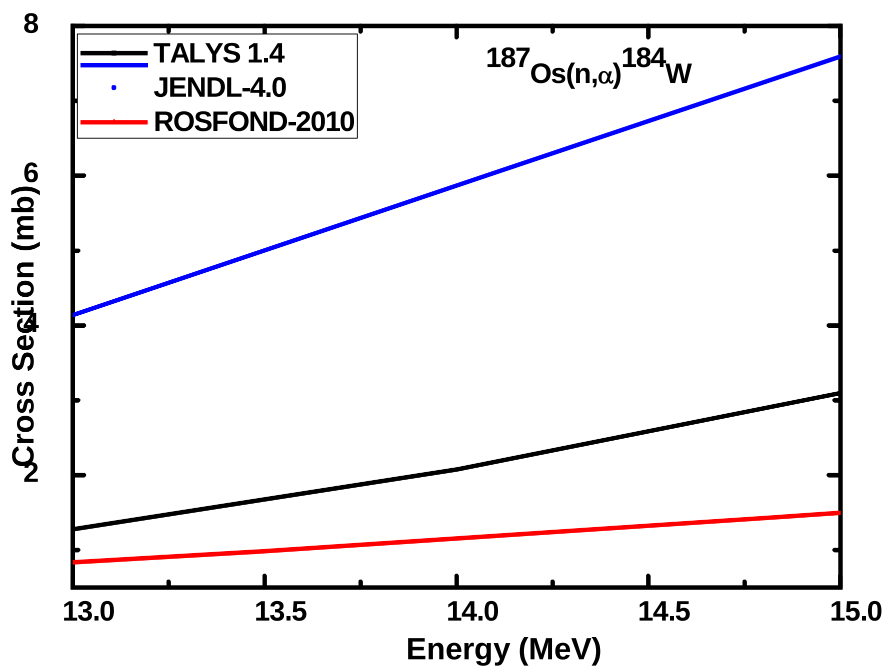

Fig7. Excitation function of the $^{187}Os(n,\alpha)^{184}W$ reaction

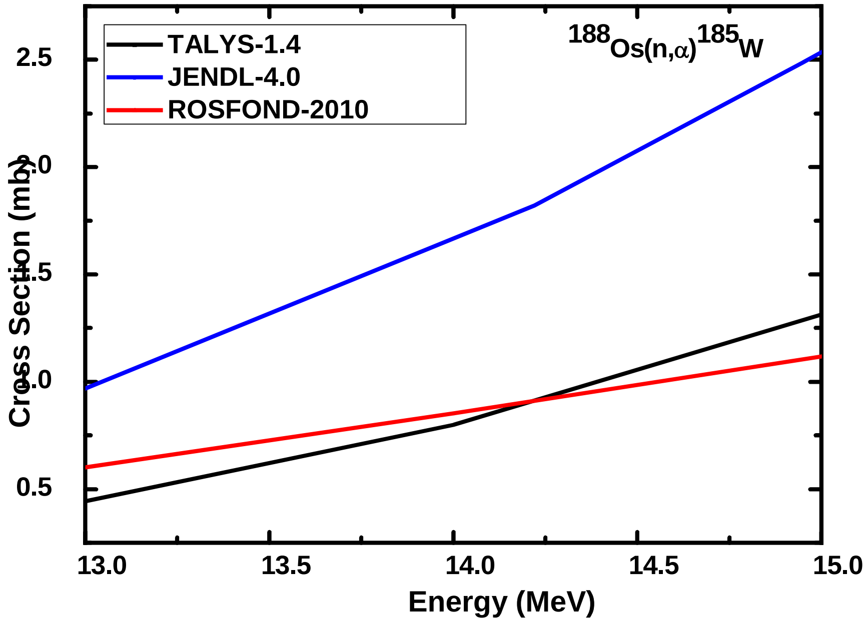

Fig8. Excitation function of the ^{188}Os(n,α)^{185}W reaction

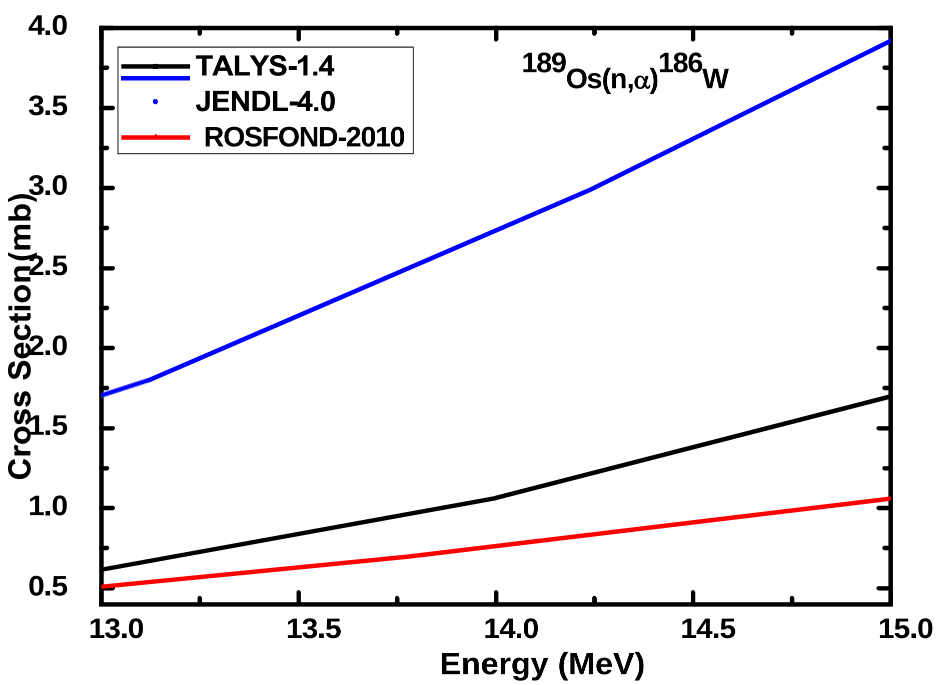

Fig9. Excitation function of the ^{189}Os(n,α)^{186}W reaction

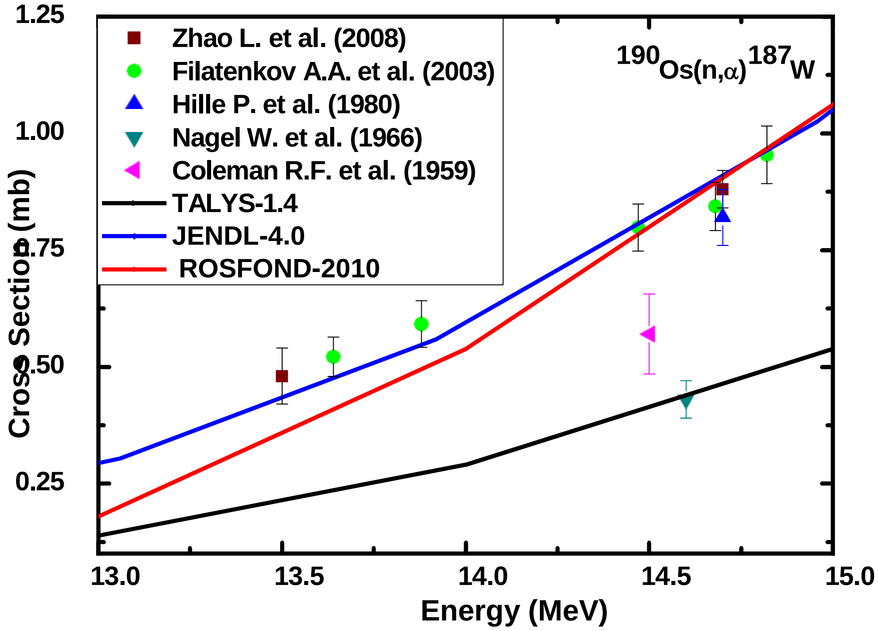

Fig10. Excitation function of the $^{190}Os(n,\alpha)^{187}W$ reaction

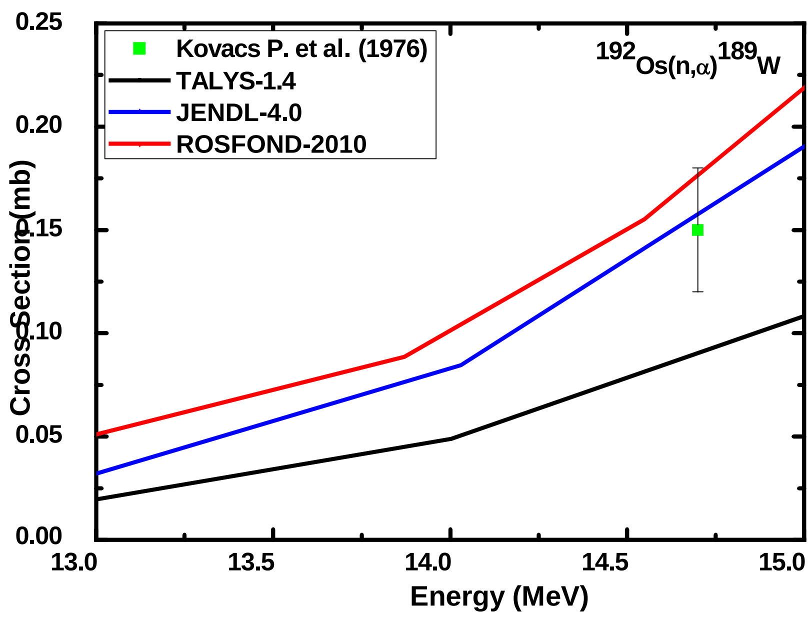

Fig11. Excitation function of the $^{192}Os(n,\alpha)^{189}W$ reaction

The results of the present investigation validate the input parameters for different neutron induced reactions on different stable isotopes of heavy transition elements of Platinum and Osmium. In the present work, the model-based calculations are done by using nuclear reaction code TALYS-1.4 [6] in the energy range from 13MeV to 15 MeV and the results are compared with different experimental values taken from EXFOR [7] data library and data files namely ROSFOND-2010 [8] & JEFF-3.2 [9] for Platinum and ROSFOND-2010 [8] & JENDL-4.0 [10] for Osmium. We have studied eleven (n, α) reactions on different isotopes of Platinum and Osmium. There are no experimental data found for $^{192}Pt(n,\alpha)^{189}Os$, $^{195}Pt(n,\alpha)^{192}Os$, $^{184}Os(n,\alpha)^{181}W$, $^{187}Os(n,\alpha)^{184}W$, $^{188}Os(n,\alpha)^{185}W$ and $^{189}Os(n,\alpha)^{186}W$ reactions (as shown in Fig.1, Fig.3,

Fig.6, Fig.7, Fig.8, and Fig.9 respectively). Limitation of activation technique due to unsuitable half-lives of product nuclei, uncertain decay scheme and unavailability of intense mono energetic neutron source account for this lack of data. From these figures we also found that data library ROSFOND-2010 [8] is in good agreement or somehow matches with the present work with pre-equilibrium exciton model from energy range 13MeV to 15MeV and therefore open for theorists for further understanding. Fig.2 & fig.4 shows excitation function of ^{194}Pt(n,α)^{191}Os & ^{196}Pt(n,α)^{193}Os reactions, from 13MeV to 15MeV. There are no sufficient experimental data for the given reactions however the data has been obtained recently by Filatenkov [13] and Coleman [14] (as shown in fig.2 & fig.4) did not match to our values in this appropriate energy range of 13MeV to 15MeV. But data libraries ROSFOND-2010 [8] and JEFF-3.2 [9] are in slight agreement with our calculated values with pre-equilibrium exciton model. In Fig.5, for excitation function of ^{198}Pt(n,α)^{195}Os reaction, experimental data with recent one available that of Uray [15] show a close agreement with the present work at 15MeV. Data libraries ROSFOND-2010 [8] and JEFF3.2 [9] are also in good agreement with our calculated values. Fig.10 show excitation function of ^{190}Os(n,α)^{187}W reaction. A very good agreement exists between present results and the data of Nagel [16] at 14.6MeV and the data obtained by Coleman [14] at 14.5MeV while the data point of Zhao [17], Filatenkov [13], Hille [18] and the data file of ROSFOND-2010 [8] and JENDL-4.0 [10] is higher or in disagreement with the present work. Fig.11 show excitation function of ^{192}Os(n,α)^{189}W reaction. The experimental value obtained by Kovacs [19] as well as data library files ROSFOND-2010 [8] and JENDL-4.0 [10] disagrees or slightly matches with our values between the energy range of 13MeV to 15MeV.

IV. Conclusion

In the present work an important improvement in description of (n,α) cross section has been obtained. This improvement is due to the simultaneous introduction of pre-equilibrium process. The (n, α) reaction cross section is calculated for Platinum, Osmium and its stable isotopes theoretically by using TALYS 1.4. The model-based calculations are done by using nuclear reaction code TALYS-1.4 in the energy range from 13MeV to 15MeV and the results are compared with different experimental values taken from EXFOR data library and data files namely ROSFOND-2010, JEFF-3.2 and JENDL-4.0. From the results, it is concluded that Back-shifted Fermi gas model level density calculations is appropriate in this energy range i.e. from 13MeV to 15MeV for the studied nuclides. It is also concluded that the folding approach for alpha optical model potential are suitable for studied nuclides in this incident neutron energy range. It is further concluded that the pre-equilibrium exciton model is suitable to calculate pre-equilibrium contribution to total (n,) reaction cross-section. It has also been concluded that Platinum, Osmium and their isotopes are widely used as reactor materials and various other applications instead of that there is less experimental data for these materials. From this analysis it has also been confirmed that the consistency of calculated results with experimental data and systematic demonstrate the predictive power of TALYS-1.4 code to predict the cross-section for the remaining isotopes of Platinum and Osmium, where no experimental data is available for target nuclei.

References

[1] D.V. Markovskij et al., “Fus. Eng. Design”, Vol 51, 695, 2000.

[2] J. C. H. Cheng et al., “Int. J. Radiat. Oncol. Biol. Phys.”, Vol 54, Issue 1, 156, 2002.

[3] T. H. Kao and W. L. Alford, “Nucl. Phys. A”, Vol 237, Issue 1, 11, 1975.

[4] P. K. Eapen and G. N. Salaita, “J. Inorg. Nucl. Chem.”, Vol 37, 1121, 1975.

[5] R. Vanska and R. Rieppo, “Nucl. Instrum. Methods”, Vol 179, 525, 1981.

[6] A. J. Koning et al., “TALYS-1.4 User’s manual A Nuclear Reaction Program NRG, NL- 1755 ZG Petten The Netherlands” 2011.

[7] EXFOR, Nuclear Reaction Data Library. www.nds.iaea.org/exfor/

[8] ROSFOND-2010, Nuclear Reaction Data Library www.nds.iaea.org/public/download- endf/ROSFOND-2010/

[9] JEFF-3.2, Nuclear Reaction Data Library www.nds.iaea.org/public/download-endf/JEFF- 3.2/

[10] JENDL-4.0, Nuclear Reaction Data Library www.nds.iaea.org/geant4/libraries/JENDL- 4.0/

[11] S. Goriely et al., “Phys. Rev. C” Vol 78, 064307, 2008.

[12] C. Kalbach et al., “Phys. Rev. C” Vol 33, 818, 1986.

[13] A. A. Filatenkov, “Khlopin Radiev. Inst. Leningrad Reports No.259” 2003.

[14] R. F. Coleman, “Proc. Phys. Soc.”, Vol 73, 215, 1959.

[15] I. Uray et al., “J. Atomki Koezlemenyek” Vol 15, Issue 3, 161, 1973.

[16] W. Nagel et al., “J. Nucl. Ener. A&B (Reactor Sci. and Technol.)” Vol 20, 475, 1966.

[17] L. Zhao et al., “Appl. Rad. Isot.” Vol 66, Issue 10, 1488, 2008.

[18] P. Hille and P. Bornemisza-Pauspertl, “Radiochim. Acta” Vol 27, 71, 1980.

[19] P. Kovacs and I. Uray, “INDC Sercretariat Rep. Ser.” Vol 60:108, 1015, 1976.

AUTHORS PROFILE

Mr. M Bhatnagar pursed M.Sc., M.Tech., and Ph.D. Physical Science from Meerut University, IIT, Delhi and University of Pierre et Marie Curie Paris, France in 1982, 1984 and 1992 respectively. He is currently working as Professor in Department of Physical Science in DIT University, Dehradun. He has published many research papers in reputed international journals including Elsevier and Springer (SCI & Web of Science) and conferences.

Mr. S K Singhal pursed M.Sc. and Ph.D. Physical Science from GB Pant University, India in 1998 and 2003 respectively. He is currently working as Faculty of Physics, Technical Education Department, Government of Uttar Pradesh, India. He has published many research papers in reputed international journals including Elsevier and Springer (SCI & Web of Science) and conferences. His main research work focuses on theoretical nuclear physics as well as the data ananlysis of neutron resonance parameters.

Mr A Badola pursed Bachelor of Science and Master of Science from HNB Garhwal University, India in year 2008 and 2010 respectively. He also pursed Master of Technology from JIIT University, India in year 2012. He is currently pursuing Ph.D. in Department of Physics, DITB University, India since 2013. He has published many research papers in reputed international journals including Elsevier and Springer (SCI & Web of Science) and conferences. His main research work focuses on theoretical nuclear physics as well as the data ananlysis of neutron resonance parameters. He has 6 years of Research Experience.