Trends and establishment of shell effects in (n, p) reaction cross-sections at 14.5 MeV

Sneh Lata Goyal
Department of Applied Physics, ,Guru Jambheshwar Universiyt of Science & Technmology, Hisar-125001, Haryana, INDIA
Email: goyalsneh@yahoo.com

Introduction

Neutron induced reaction cross-sections are basic data required for design calculations in nuclear technologies that involve neutrons, in particular for fusion and fission reactors, study of reaction mechanism, in extracting useful information about nuclear structure, neutron dosimetry, radiation damage to materials, activation analysis, shielding etc.. The need for fast neutron induced reaction cross-section data has been increasing in several applied fields; for example, biomedical applications such as production of radioisotopes and cancer therapy, accelerator-driven transmutation of long-lived radioactive nuclear wastes to short lived or stable isotopes by secondary spallation neutrons.

It is not feasible to carry out experimental measurements for all the target nuclei. The inadequate experimental data are supplemented by calculated results based on nuclear reaction model codes. However, availability and complexity of such computer codes pose problems for easy and quick estimation of the neutron emission data particularly for thick target neutron yield distributions. A large number of empirical and semi-empirical formulae with different parameters for cross-section calculations of the reactions (n, p), (n, α) and (n, 2n) at the different neutron energies have been proposed by several authors.

In the present work , an attempt has been made to develop an empirical relation for (n, p) reaction cross-sections at 14.5 MeV neutron energy using least square fitting which shows the Z/A dependence of the (n, p) reaction cross-sections as in Fig. 1. Such empirical relations can be very useful for predicting cross-sections of the isotopes when experimental data are not available. Shell effects have also been established at magic neutron numbers N = 20, 28 and 50 by the plots of $\sigma_{n,p}$ vs. N.

Results and Discussion

A comprehensive review of the measured data for 14.5 MeV neutron induced reaction cross-sections for (n, p) reaction has been made for the isotopes having Z up to 83. Using the available data of 14.5 MeV neutron energy for 218 nuclei having $0.39 \leq Z/A \leq 0.46$ an empirical relation for (n, p) reaction cross-sections have been derived using least squares fitting. A regression model have been developed which predicts the cross-sections vs. Z/A for these isotopes. Different regression equations were tried and the exponential trend was found to give the best fit equation as shown in fig. 1. The empirical relation thus obtained for (n, p) reaction cross-sections is given by

$$\sigma_{n,\,p} = \alpha \exp(\beta\, Z/A) \quad \text{(mb)} \qquad (1)$$

where α and β are fitting parameters. They have the following values:
$\alpha = 5.0 \times 10^{-11}$, $\beta = 61.581$
The coefficient of determination is given by $R^2 = 0.8416$

The validity of these fittings is defined by R-square i.e. coefficient of determination or square of the correlation coefficient which when equals to 1, indicates the best fit [1,2,4]. It is % variability defined by the fitting equation. The model which gives maximum R^2 is selected as this interprets the maximum variability in data set.

The values predicted with above equation are compared with the experimental data. Such comparison [1-3] of the predicted cross-sections with the experimental values shows that the agreement is quite satisfactory.

For N = 20-46, plots of $\sigma_{n,p}$ vs. N have been shown in fig. 2 for N–Z = 2, 3, 5 and 8. For N–Z = 2 and 5 the shell effect is clearly satisfied with minima at N = 28 for $^{51}V_{28}$ and $^{54}Fe_{28}$ as compared to the neighboring isotopes. When N–Z = 3 and 8, one sided minima have been observed at magic neutron numbers N = 20 and 28 as no data are available on their left side.

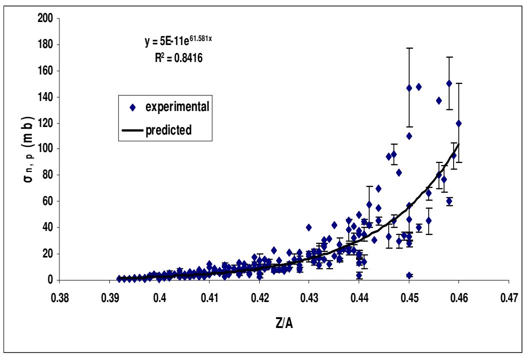

Fig. 1

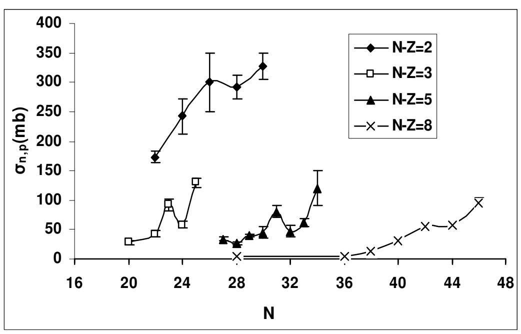

Fig. 2

Fig. 3 shows plots of $\sigma_{n,p}$ vs. N having shell effect with minima at N = 50 for the isotopes $^{90}Zr_{50}$, $^{89}Y_{50}$ and $^{87}Rb_{50}$ for N–Z = 10, 11 and 13 respectively as compared to their neighboring isotopes.

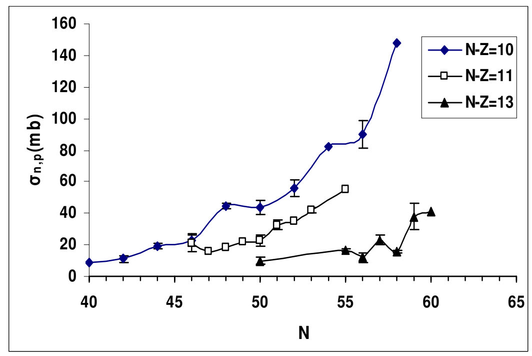

Fig. 3

References

[1] S. L. Goyal, Nawal Kishore, *Indian J. Phys*. (2009) (accepted).

[2] S. L. Goyal, P. Gur, *Pramana-J. Phys*. **72**, 355 (2009).

[3] S. L. Bansal (nee goyal), R. K. Mohindra, *Ind. J. Phys.* **69A,** 361 (1995).

[4] M. Maiti, M. Nandy, S. N. Roy, P.K. Sarkar, *Pramana-J. Phys.* **60,** 143 (2003).