Study on single neutron Spectroscopic Factor of the neutron rich and shell closed nuclei using (d,p) reactions.

A. Vinayak, M. M. Hosamani, P. N. Patil and N. M. Badiger*
Department of Studies in Physics, Karnatak University, Dharwad – 580003, India
*email: nbadiger@gmail.com

Introduction

Transfer reaction is an important tool to probe the structure of a nucleus. The occupancy of nucleons in a nucleus can be understood using the Spectroscopic Factor (S.F.). The stripping (d,p) and pick up (p,d) reactions are used to determine the spectroscopic factor and comparison would validate the nuclear shell model [1].

Experimentally, both transfer and knockout reactions have been widely studied in order to determine the Spectroscopic factor of single-nucleon orbits. However, their extracted SF of the experimental measurements often varied widely with standard theoretical predictions. Theoretical predictions reflecting inconsistencies in the choice of optical potentials for the incoming and outgoing channels to where the transfer reaction is highly sensitive. The differential cross-section of the (d,p) reaction angular distribution is estimated through the finite range DWBA (Distorted Wave Born Approximation) model. In the present investigation, theoretical calculation covers the energy range 3 MeV to 26 MeV at Lab frame [2] for most of the doubly shell closed and neutron rich and neutron shell closed nuclei. The theoretical differential cross section values obtained from DWUCK5 [3,4] and FRESCO [5] have been compared with the experimental values in order to obtain S.F values. The SF values so obtained compared with the values predicted by theoretical model like LBSM (Large Basis Shell Model), IPM (Independent Particle Model) and also experimentally determined S.F values by other investigators.

$$\left(d\sigma/d\Omega\right)_{Expt} = S\left(d\sigma/d\Omega\right)_{Theory} \quad \text{---- (1)}$$

Where S is the spectroscopic factor.

The value of spectroscopic factor extracted from ratio of experimental measured differential cross section to theoretical differential cross section. Using transfer reactions, the transition strength between the initial and final states of the nucleus can be obtained . The salient features of the spectroscopic factor are well established by several investigators [6]. Using the above expression, SFs of ground state transition of target nuclei those are doubly shell closed and neutron rich and neutron shell closed in the different mass region of the periodic table have been determined.

Details of Calculation.

In this investigations we have determined SF values for the 21 nuclei using the finite range DWBA method. Comparison of our Spectroscopic factor values with those determined experimentally indicate good agreement within uncertainties.

Our main concentration to analyze the (d, p) reaction at low energy range where the break-up of deuteron contribution is negligible .We have selected and compiled low energies angular distribution of (d, p) data, which are extracted from various published papers in international journals [2,6,7]. The data extracted and obtained here for the target nucleus which covers the low Z to high Z nuclei. Range of the data extracted for the systematic study covers for the doubly closed nuclei from N=8, Z=8 to N=126, Z=82 and for neutron closed and neutron rich nuclei from N=8, Z=6 to N=82, Z=50. We analyze theoretical cross-section for the single particle neutron state for ground state transition using DWBA model and deduce the spectroscopic factor by comparing its value with experimental cross-section (Eq. 1). For most of the reaction we include best fitted elastic scattering potential parameter to entrance as well as exit channel both given by the reference [8].

Result and discussion –

For the isotopes of nuclei ranging from ^{13}C to ^{209}Pb of neutron rich, neutron closed and doubly shell closed; the SF have been estimated at different projectile energy of (d, p) reaction. The extensive study of the energy functioned spectroscopic factor have need to be carried out to get a clarification over the SF dependency on the projectile energy. The determined spectroscopic factors from our calculation for the same nucleus are having bit variation with deuteron energy. These values are having close agreement with spectroscopic factor of others investigations. This compilation probes the effectiveness finite range DWBA approach for doubly closed nuclei over the range of low Z to high Z nuclei and also the exotic neutron rich nuclei. It is interest to know about the structure of the nuclei having a nucleon just next to doubly closed shell. Here we also complied the S.F values of various neutron rich nuclei since to study the occupancy at ground state of neutron for exotic neutron rich nuclei, we observe the low of the S.F. for these kind of nuclei. The compilation approaches the almost all doubly closed nuclei as a target in a (d,p) reaction which are having S.F values nearly unity within the uncertainty.

This investigation lead by the interest rose due to presence of neutron rich as well as neutron magic number which are showing the SF special trend with respect to the ratio of neutron separation energy to asymmetric factor,$(N-Z)^2/A$. The obtained special behavior for the neutron rich as well as neutron shell closed nuclei is shown in figure 1. The S.F among decided 21 nuclei are studied systematically which contains the doubly shell closed, neutron rich and neutron closed as well as neutron rich targets.

Thus we obtained the interesting results through (d,p) one neutron stripping reaction for ground state. The dependency of the S.F. on the projectile energy, neutron separation energy etc. are discussed. The complete results of this compilation of the (d,p) reaction will be presented at the symposium.

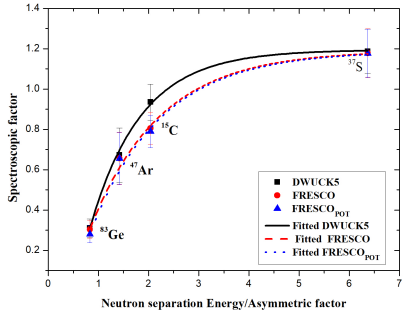

Fig. 1 Relation between S.F and ratio of neutron separation energy to asymmetry factor for nuclei which are both neutron rich as well as neutron closed.

References

[1] N. Austern Direct Nuclear Reaction theories (Wiley New York, 1970)
[2] X.D. Liu et.al Phys. Rev. C 69.064313(2004).
[3] http://nrv.jinr.ru/nrv/webnrv/transfer/NRVtransfer.pdf
[4] P. Kunz. Finite range dwba code dwuck-5. http://spot.colorado.edu/_kunz/DWBA.html, 1990
[5] I. J. Thompson, Comp. Phys. Rep. 7, 167 (1988).
[6] J. Lee et. al Phys. Rev. C 75.064320(2007)
[7] J. S. Thomas *et al.*, Phys. Rev. C **76**, 044302 (2007)
[8] C.M.Perey and F.G.Perey . At. Data Nucl. Data Tables 17,1-101(1976)

Acknowledgement-
One of the authors (AV) would like to acknowledge DST-PURSE-PHASE-II for providing the financial assistance in the form of Project Fellow at Department of Physics, Karnatak University, Dharwad, India.