Transfer reaction measurements for ^{28}Si + ^{92,96}Zr systems

Khushboo[1],* S. Mandal[1], S. Nath[2], N. Madhavan[2], J. Gehlot[2], A. Banerjee[1], N. Kumar[1], Tathagata Banerjee[2], G. Kaur[3], K. Rojeeta[1], Unnati[1], A. Jhingan[2], T. Varughese[2], Indu Bala[2], S. Muralithar[2], R. P. Singh[2], Visakh A. C.[4], Ch. Vikar[1], H. Arora[3], Sarvesh[5], S. Kumar[1], S. Verma[1], and P. Verma[5]

[1]*Department of Physics &Astrophysics, University of Delhi, Delhi - 110007, India*
[2]*Inter University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi - 110067, India*
[3]*Department of Physics, Panjab University, Chandigarh - 160014, India*
[4]*Department of Physics, Central University of Kerala, Nileshwar-671314, India and*
[5]*Department of Physics, Kalindi College University of Delhi, New Delhi - 110008, India*

Introduction

Transfer reaction is an important mechanism for spectroscopic studies as well as for probing several aspects of nuclear reactions. It is a multi-step process which can take place either successively or via pair transfer (simultaneous) mode. Transfer reaction provides a tool to investigate the pairing correlations in nuclei and the dynamics of quasi-elastic to deep-inelastic transition regime [1]. The importance of pairing correlations in nuclei has been investigated by several authors and an odd-even staggering in transfer probability has been observed [2]. Transfer channel also has a great impact on fusion process and contribute significantly to sub-barrier fusion enhancement [3].

In the present paper, we are reporting the transfer measurements for ^{28}Si+^{92,96}Zr systems. The target nuclei ^{92,96}Zr have closed shell for protons which allows one to investigate the effect of proton shell closure on transfer mechanism. The target ^{92}Zr has positive Q-value for 2n pick up channel with the Q-value negative for 1n pick up channel. Therefore, pair transfer mode is expected to be dominant for ^{28}Si+^{92}Zr making this system adequate for understanding pairing correlations. The other target, ^{96}Zr can be an appropriate candidate to explore the odd-even effect due to the presence of six neutrons outside its closed shell. One of the major challenges in the study of transfer reactions is to have a good mass and charge resolution for proper identification of transfer products which can be achieved with a recoil mass separator.

*Electronic address: s12khushboo@gmail.com

Experimental Details

The experiment was performed at the Inter University Accelerator Centre (IUAC), New Delhi with ^{28}Si pulsed beam of 1 μs repetition rate from Pelletron. It was used to bombard isotopically enriched ^{92}Zr (95.13%) and $^{96}ZrO_2$ (86.4%) targets. These targets were prepared by electron beam evaporation technique in the target laboratory of IUAC. The measurements were carried out around the Coulomb barrier at laboratory energies 94, 91 and 88 MeV.

The Heavy Ion Reaction Analyzer (HIRA) facility [4] of IUAC was used to perform the experiment and it was placed at 6^0 with respect to beam direction to improve the beam rejection. The solid angle aperture of 1 mSr was kept at the entrance of HIRA. A Multi-Wire Proportional Counter (MWPC) with dimensions 152.4 x 50.8 mm^2 was placed at the focal plane of HIRA to detect the recoil transfer products. MWPC was kept at a pressure of 3.5 mbar of isobutane gas. A position sensitive Silicon detector with an effective area of 21 x 21 mm ^{2} was mounted at the phop disc of the target chamber at the corresponding backward angle to detect the projectile-like backscattered particles. The angular position of this detector was optimized through maximization of coincidence counts between the focal plane and Silicon detector. Since the transfer reaction is a multi-step process and interacting nuclei can get excited before or after transfer of nucleons, therefore, to extract contribution from excited states, 14 element BGO (Bismuth Germanate Oxide) multiplicity filter was mounted on top and bottom of the target chamber. A 3-fold kinematic coincidence was set up between focal plane MWPC, Silicon detector and BGO. Inside the target chamber, two Silicon Surface Barrier Detectors (SSBD) were placed at an angle of $\pm 15^0$ with respect to beam direction which were used to monitor the beam. A carbon charge reset foil (30 μg/cm^2) was placed at a distance of 10 cm from the target for equilibration of the charge state of recoil reaction products. In order to separate recoil products from beam like scattered particles, a time of flight (TOF) was defined between Anode of MWPC and RF signal of the beam. Online data was recorded using Freedom software.

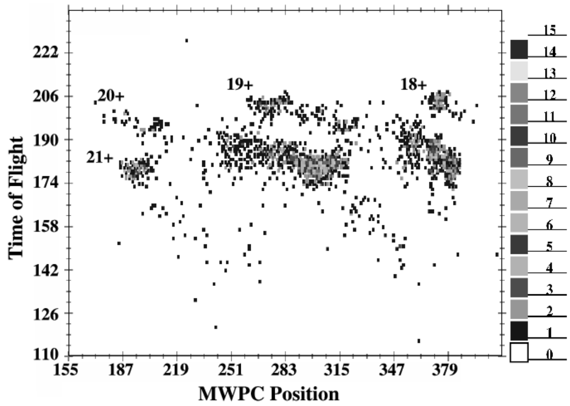

FIG. 1: Two-dimensional spectrum of Time of Flight vs MWPC position for ^{28}Si+^{96}Zr system at 88 MeV projectile energy.

Results

A two-dimensional spectrum as shown in FIG. 1 was created between TOF of recoils and MWPC position which was gated with back detector Silicon energy. In this spectrum, different transfer products are separated according to their Mass/Charge (M/q) ratio. A mass spectrum obtained by projecting the 2-D spectrum on x-axis (MWPC position) is shown in FIG. 2. Further analysis is under progress.

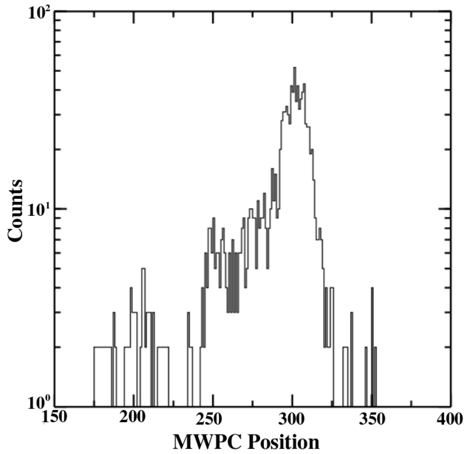

FIG. 2: Mass spectrum obtained by projecting the 2-D spectrum of Time of Flight vs MWPC position for ^{28}Si+^{96}Zr system at 88 MeV projectile energy.

Acknowledgments

We are extremely thankful to entire Accelerator (Pelletron) group for providing a stable beam. We also want to thank target laboratory members, especially Abhilash S. R. for the help during preparation of targets. The financial support of the IUAC research project under UFR-51314 is gratefully acknowledged.

References

[1] L. Corradi, G. Pollarolo, and S. Szilner, J. of Phys. G **36**, 113101 (2009).

[2] S. Kalkal *et al.*, Phys. Rev. C **83**, 054607 (2011).

[3] S. Kalkal *et al.*, Phys. Rev. C **81**, 044610 (2010).

[4] A. K. Sinha *et al.*, Nucl. Inst. Meth. A **339**, 543 (1994).