ER excitation function for ^{31}P + ^{170}Er

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Introduction

Shell closure is known to give nuclei extra stability and its effect on reaction dynamics has been an area of investigation for a long time. It is evident that shell closure of target [1] or compound nucleus (CN) [2, 3] influences the fusion fission dynamics. These studies are particularly important for the synthesis of super heavy elements (SHE), which are predicted to survive due to shell correction energy. Cross sections of formation of SHE are very small ($\lesssim 1$ pb) and hence it is very important to know the reaction dynamics very well before choosing a target projectile combination for SHE production. This motivated us to study the effect of shell closure of CN in mass 200 region using evaporation residue (ER) cross section and ER-gated spin distribution as probes. This region is particularly important as it is the region of highest closed shell stable nuclei. We have measured ER cross section and ER-gated gamma-multiplicity for the reaction ^{31}P + ^{170}Er which forms CN ^{201}Bi, having an extra proton outside the closed shell $Z = 82$. Gamma-multiplicity distribution was reported earlier [4] and now we have extracted the ER cross sections for this reaction.

Experimental details

The experiment was carried out at IUAC using 15UD Pelletron + LINAC facility. ^{31}P and ^{30}Si beams at energies from 134 to 177 MeV were bombarded on ^{170}Er target. Target of enriched ^{170}Er (97% enrichment), having thickness 130 μg/cm^2, was prepared using vacuum evaporation technique at IUAC target laboratory. Er was sandwiched between two carbon layers of thicknesses 45 (beam facing) and 23 μg/cm^2. ERs were separated from the intense beam background using the HYRA [5] which is having the configuration Q-Q-MD-Q-MD-Q-Q where, Q and MD stand for quadrupole and magnetic dipole, respectively. HYRA was operated in gas-filled mode with helium at a pressure of 0.15 torr. The TIFR 4π spin spectrometer [6] was used for detection of gamma-rays in coincidence with ERs. The target chamber, with an inner diameter of 12 cm, was placed at the centre of the spin spectrometer [7]. An SSBD detector was put at an angle of 25.9° to detect elastically scattered particles. Distance of SSBD from target was 2.3 cm. ERs were transported to the focal plane and detected with the help of a 5×15 cm^2 multi wire proportional counter (MWPC), which was followed by a double sided Si strip detector. Each side of the strip detector had 16 strips. Time of

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flight technique was used to separate ERs from beam like contamination, if any. For this purpose, pulsed beam was used with repetition rate of 2 μs. A time to amplitude converter (TAC) was set between the MWPC anode and RF signals. A 2D spectrum, between TAC and energy loss in MWPC, allowed separation of ERs from contaminants. No significant contamination from the beam-like particles was observed.

Results and analysis

ER cross section was extracted using the formula

$$\sigma_{ER} = \frac{Y_{ER}}{Y_{Mon}} \left(\frac{d\sigma}{d\Omega}\right)_{Ruth} \Omega_{mon} \frac{1}{\eta_{HYRA}} \quad (1)$$

where, Y_{ER} and Y_{Mon} are yields for ER and elastic channels, respectively. $(d\sigma/d\Omega)_{Ruth}$ is the differential Rutherford cross section, Ω_{mon} is angle subtended by the monitor detector and η_{HYRA} is transmission efficiency of the HYRA. η_{HYRA} was extracted using the reaction ^{30}Si + ^{170}Er as the reference, for which ER cross-section had been reported earlier [8]. This method of estimating η_{HYRA} was used earlier by Prasad et. al. [9]. We recorded ER for ^{30}Si + ^{170}Er at energies 152.13, 160.52 and 172.66 MeV η_{HYRA} was extracted for ^{30}Si + ^{170}Er. Fig. 1 shows the preliminary results of our analysis. Capture cross section (calculated using the code CCFULL [10]) and ER cross section calculated from statistical model are also shown. For statistical model calculation, it was considered that CN decays through either fission or evaporation of proton, neutron, α particle or emission of γ-rays. Spin distribution of CN, for statistical model calculation, was taken from CCFULL calculation which included rotational coupling of the target. Experimental values are comparable with the prediction of statistical model. The process of comparing this system with neighboring shell closed CN is in progress.

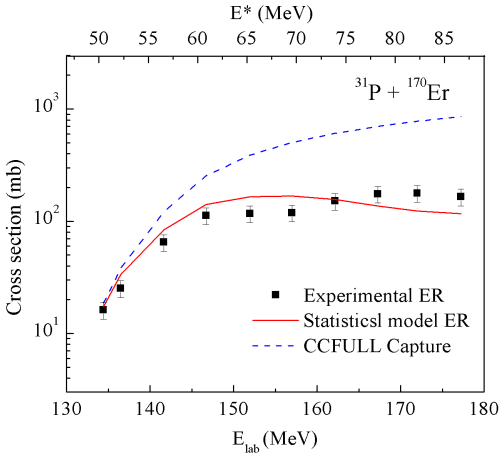

FIG. 1: ER excitation function (preliminary) for the reaction ^{31}P + ^{170}Er.

Acknowledgments

We thank Pelletron and LINAC crew of IUAC, New Delhi for providing excellent beam during the experiment. We acknowledge the help received from target laboratory, especially Mr. Abhilash, during target preparation. We also thank Dr. D. Mehta for his help in XRF measurement of the target. One of the authors (GM) wants to acknowledge CSIR, for supporting through scholarship.

References

[1] K. Satou *et al.*, Phys. Rev. C **65**, 054602 (2002).
[2] A. Shrivastava *et al.*, Phys. Rev. Lett. **82**, 699 (1999).
[3] S. Nath *et al.*, Phys. Rev. C **81**, 064601 (2010).
[4] Gayatri Mohanto *et al.*, DAE Symp. on Nucl. Phys. **56**, 566 (2011).
[5] N. Madhavan *et al.*, Pramana -J Phys **75**, 317 (2010).
[6] G. Anil kumar *et al.*, Nucl. Instr. Meth. A **76**, 611 (2009).
[7] N. Madhavan *et al.*, EPJ Web of Conferences **17**, 14003, (2011).
[8] D. J. Hinde *et al.* Nucl. Phys. A **385**, 109 (1982).
[9] E. Prasad et al., Phys. Rev. C. **84**, 064606 (2011).
[10] K. Hagino *et al.*, Comput. Phys. Comm. **123**, 143 (1999).