Observation of Multistep Coulomb Excitation during Ion-Atom Collisions

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Introduction

Well below the Coulomb barrier energies two colliding nuclei may share the energy via electromagnetic interactions and it can lead to excite the nuclear states of one or both the participating nuclei. This long range Coulombic interaction leading to nuclear excitation is called Coulomb excitation [1]. In the present work, we have studied heavy ion induced Coulomb excitation process in ^{12}C nuclei at the sub-Coulomb barrier energies using x-ray spectroscopy technique in combination with the nuclear techniques.

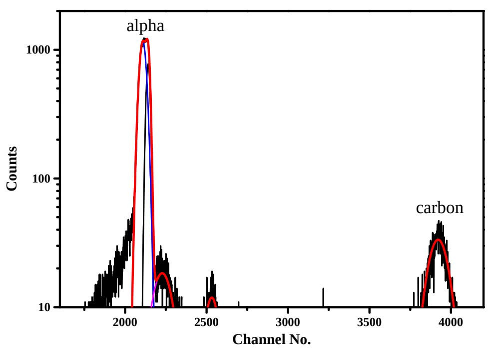

FIG. 1: A typical particle spectra observed as in the reaction ^{12}C(^{58}Ni,X) at 120 MeV

Experimental setup

Experiments were performed at the 15 UD Pelletron accelerator IUAC, New Delhi. Well-collimated energetic ion beam of ^{56}Fe (104 MeV) and ^{58}Ni (120 MeV) were bombarded on 80 μg/cm^2 thick amorphous carbon target foils. The target was placed at 45° to the beam axis. The x-rays produced in reactions were detected in two germanium ultra-low energy detectors (GUL0035, Canberra Inc., with 25 μm thick Be entrance window, resolution 150 eV at 5.9 keV) placed at ±90° to the beam axis to minimize the Doppler shift. Detectors were kept outside the chamber at 16 cm (LEGe1) and 65 cm (LEGe2) away from the target. Target-like fragments were detected in a microstrip detector, which were placed at 30 ° and 46 cm from the beam axis and center, respectively. Microstrip detector was calibrated using ^{241}Am α source, whereas the x-ray detectors were calibrated using ^{60}Co and ^{241}Am standard radioactive sources. Typical particle spectrum observed is shown in the Fig. 1. Through offline measurements, it had been confirmed that first peak (large along with a side small peak) corresponded to the α particles and the second peak was due to the elastically scattered carbon.

Results and Discussion

It is well-known that breakup energy threshold of the reactions $^{12}\text{C} \rightarrow \alpha_1 + \alpha_2 + \alpha_3$ and $^{12}\text{C} \rightarrow {}^{8}\text{Be} + \alpha$ are 7.65 MeV and 7.367 MeV, respectively [2]. Kinematic calculations suggest that the large peak belongs to $^{12}\text{C} \rightarrow \alpha_1 + \alpha_2 + \alpha_3$ and the small peak for $^{12}\text{C} \rightarrow {}^{8}\text{Be} + \alpha$. In this work we are emphasising on the sharp peak. In next step, we have gated the large α peak on the raw x-ray spectra. Typical x-ray spectra with the α-x-ray coincidence are shown in the Fig. 2 for both the projectiles. It is observed that the main source of these α particles is due to projectile ions or in other words Coulomb excitation. Interestingly we have also observed the formation under the projectile-like fragment

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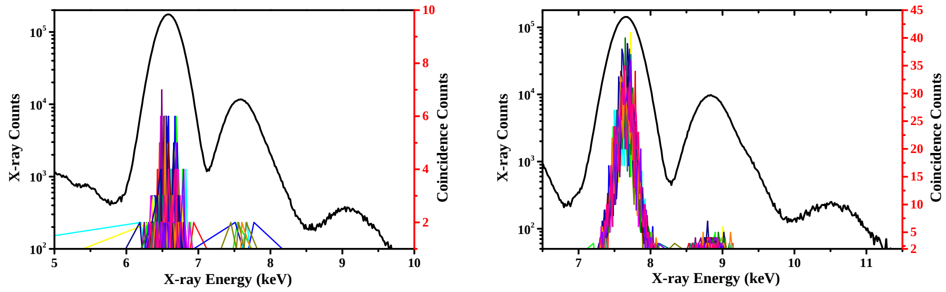

FIG. 2: X-ray spectra (black) and α-x-ray coincidence spectra (colour) for (a) 104 MeV ^{56}Fe beam and (b) 120 MeV ^{58}Ni beam on 80 μg/cm^2 C-foil. It is evident from both the x-ray spectra that they contains mainly three structures. In our earlier work the first peak is recognized to have originated from the projectile ion x-ray, whereas second and third peak belong to the projectile-like fragment ions emanating from the nuclear reactions, respectively [3, 4].

(PLF) ion x-ray peak. This clearly suggest that there is multiple coulomb excitation taking place in the bulk of the target, in which energetic projectile-like fragment ion (nuclear reaction product) again excite the carbon atom to break into three α particles.

Conclusions

Atomic technique has been involved with nuclear techniques to explore Coulomb excitation phenomena. Interestingly, it is found that PLF ion may also induce the Coulomb excitations in the target nuclei.

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