Emission of α-Particle in the Interaction of ^{14}N with ^{59}Co, ^{93}Nb and ^{197}Au at Incident energy of 250 MeV

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Introduction

At the projectile energies of 200 MeV and above, heavy ion induced pre-equilibrium emission of nucleons, light charged particles and evaporation residues presents a challenge towards our understanding of physics involving heavy ion reaction mechanism [1]. It is well established that in heavy ion reactions, the compound nucleus mechanism is competing with non-equilibrium and direct reaction processes which are even more dominant at high energies [2]. Most of these alpha particles originate from projectile break-up [3]. There are very few theoretical codes available which addresses the domain of non-equilibrium emission of alpha particles in heavy-ion reactions and give a reasonable account of experimental data obtained over a large incident energy and target-mass range.

In the present work, we aim to investigate about the contribution of direct processes, pre-equilibrium emission and evaporation of particles at such a high incident energy. For this we are testing a new theoretical approach which have been developed by O.V. Fotina, *et al.* [4] based on Griffin's model of non-equilibrium processes to describe the spectra of nucleons and other light particles emitted in the non-equilibrium stage of compound nucleus formation. For this purpose the statistical code PACE was modified [5] to accommodate the pre-equilibrium process calculations at sufficiently high energies.

In this work we have presented the results of measured inclusive double differential cross sections of alpha particles emitted in the interaction of ^{14}N with ^{59}Co, ^{93}Nb and ^{197}Au at incident energy of 250 MeV. The experimental data were collected in a wide angular range from 8 to 100 degrees in the laboratory system. We have compared our experimental results with the calculations done using above mentioned modified PACE theoretical model code. This will put the code to a stringent test as to how it performs in case of heavy ion reactions at such high energies.

Experimental procedure

The experiment was performed at the cyclotron facility of the iThemba LABS, Somerset West, South Africa, where the beam of ^{14}N ions of 250 MeV energy was supplied. A detailed description of the facility can be found in J.V. Pilcher, *et al.* [6]. The beams were focused on the target mounted at the center of a 1.5 m diameter scattering chamber. The targets were mounted in aluminium frames with 25 mm diameter apertures. The ^{59}Co, ^{93}Nb and ^{197}Au target thicknesses were 1.00 mg/cm^2, 1.72 mg/cm^2 and 3.54 mg/cm^2 respectively. A set of two ΔE-E Si surface-barrier detectors were used whose thicknesses were selected in such a way so as to cover both a lower and a higher energy region. One telescopes had thicknesses of 30 μm and 500 μm while the other had thicknesses of 100 μm and 2000 μm, respectively. By combining the data from both the telescopes, complete energy spectra was obtained. Data were acquired at various scattering angles ranging from 8°-100°. The overall systematic uncertainty of the absolute cross section values is estimated to be less than 10%.

Results and Discussion

Figs. 1 shows the energy spectra of alpha particles at various angles in the reaction of ^{14}N with ^{59}Co, ^{93}Nb and ^{197}Au at an incident energy of 250 MeV. It can be seen that at very forward angle (8˚) the cross-section remains almost constant for alpha-particles emitted with energies between 40 MeV to 80 MeV for all the targets, and a rapid decrease in the cross-section thereafter. But at higher angles there is no such constant region and the cross-section keeps on decreasing rapidly with alpha particle energy. The "flat" region in the alpha spectra for forward angle curve can be said to have majority of contribution from alpha which are re-emitted with reduced energy after undergoing fusion. But this trend decreases rapidly towards higher energies. This indicates that there is ~50-70% decrease in energy of an alpha particle after the fusion, when it is re-emitted.

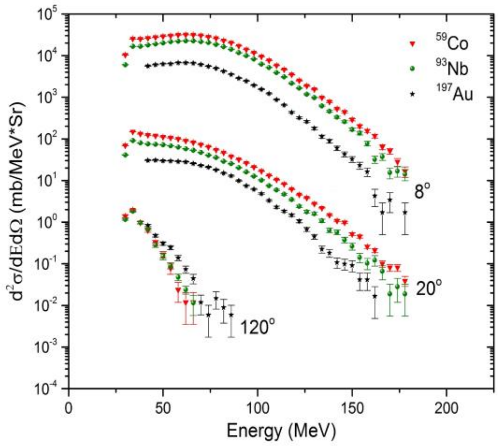

Fig. 1 Experimental double differential α-particle spectra for the interaction of ^{14}N with ^{59}Co, ^{93}Nb and ^{197}Au at incident energy of 250 MeV.

As we go towards the region of higher energy alpha particles, it is seen that the contribution of alpha particles coming from break-up, transfer and other non-equilibrium phenomena become dominant which are responsible for a high-energy tail.

Figure 2 shows the comparison between experimental results with modified PACE code results at various angles. It is seen that there is a good agreement between two at mid angles and backward angles which indicates that pre-equilibrium emission is the only dominant mechanism remaining in this region.

Due to lack of space, results for forward angles are not shown here. But at very forward angles there is a significant "gap" between experimental and theoretical results. This "gap" between experimental and calculated results indicate that at forward angles apart from pre-equilibrium emission, direct reactions also contribute significantly to the cross-sections. From current results, contribution from direct reactions cannot be calculated exactly but we can still have some estimate about it. This points to the need of a code which will be able to calculate all the above mentioned reaction contribution for heavy ion reactions.

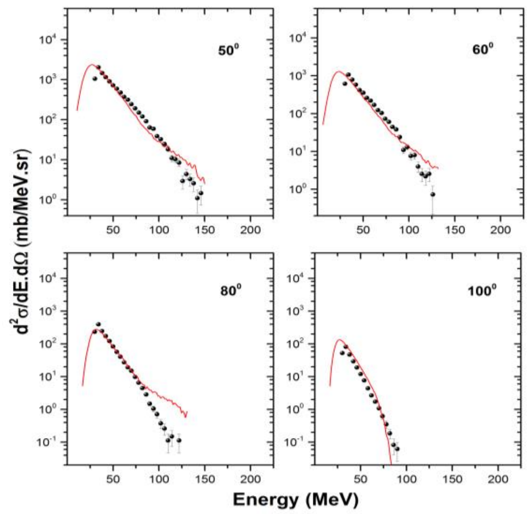

Fig. 2 Comparison between experimental and theoretical alpha energy spectra for the interaction of ^{14}N with ^{59}Co. Solid spheres (black) are experimental data points which include error bars and the results of modified PACE4 are shown as solid curve (red).

References

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