Fragment emission mechanism in ^{20}Ne + ^{56}Fe and ^{16}O + ^{58}Ni reactions

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Introduction

Heavy ion-induced nuclear collisions are a powerful approach for generating isotopes with different neutron-to-proton ratios among various charged particles. By detecting the exit channel particles with distinct masses and charges, the equilibration signatures across different degrees of freedom can be effectively analyzed. In fusion-fission or compound nuclear type reactions, the emitted source tends to reach equilibration across all degrees of freedom, particularly at low excitation energies of the composite system. However, as the excitation energy of the composite system increases, additional non-equilibrium exit channels become accessible, disrupting the equilibrium among the different degrees of freedom. Exploring the characteristics of non-equilibrium nuclear reactions offers valuable insights into the level of equilibration achieved before the fragmentation of the composite take places. The 'deep inelastic reaction' is particularly intriguing in this context, as it represents an intermediate process between compound and direct nuclear reactions [1,2]. The isospin of the emitted fragments are found to be the first degree of freedom equilibrated prior to the emission from the hot composites form in different reactions [3]. But in recent studies it has been observed that fragmentation took place before the complete equilibrium of N/Z at beam energy higher than the Fermi energy [3]. At lower beam energies, the interaction time is generally longer compared to that at higher beam energies, suggesting that the system is likely to achieve equilibrium, at least in terms of isospin degrees of freedom, before the fragmentation of the entire system, even in peripheral collisions. We have explored the isospin equilibrium in fragment emission mechanism from deep inelastic collision at low beam energy (< 10MeV/A) [4]. In the present paper, fragment emission mechanism; particularly the isospin, N/Z, equilibrium has been studied by measuring the isotopes of the complex fragment emitted in the reactions, ^{20}Ne + ^{56}Fe and ^{16}O + ^{58}Ni at beam energy (18 - 24 MeV/A).

Experimental Details

The experiment was performed using ^{20}Ne (360 MeV and 440 MeV) and ^{16}O (343 MeV and 363 MeV) beams from the K500 superconducting cyclotron [5] at VECC, Kolkata, on ^{56}Fe and ^{58}Ni targets, respectively. Inclusive as well as exclusive energy and angular distributions of the fragments measured isotopically up to Z = 7. Four si-strip telescopes [6], two on either sides of the beam axis, have been used inside a large scattering chamber called SHARC [7] for the measurements of the outgoing charged particles. The Particle identification spectrum obtained by the ΔE-E method is shown in Fig.1 for the ^{20}Ne+^{56}Fe reaction at 360 MeV. It is cleared from Fig.1 that a very good isotopic separation of various fragments were achieved.

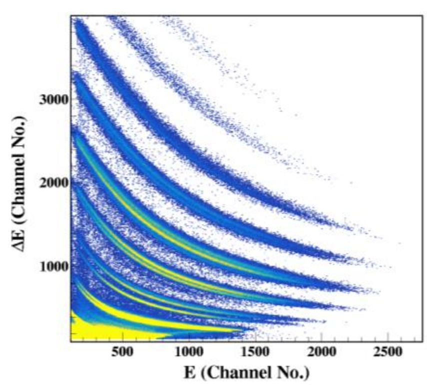

Fig.1: Particle identification spectrum at 30^0.

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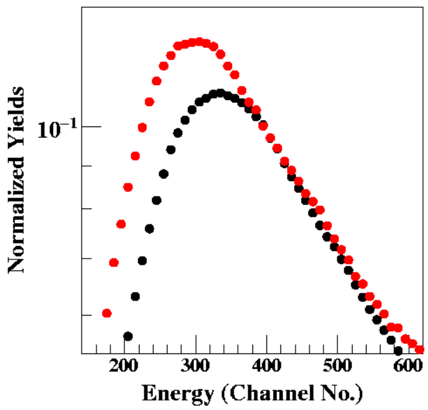

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Fig. 2: Energy distributions of α at 30^0 in reactions ^{16}O (343 MeV) + ^{58}Ni (red solid circles) and ^{20}Ne (363 MeV) + ^{56}Fe (black solid circles).

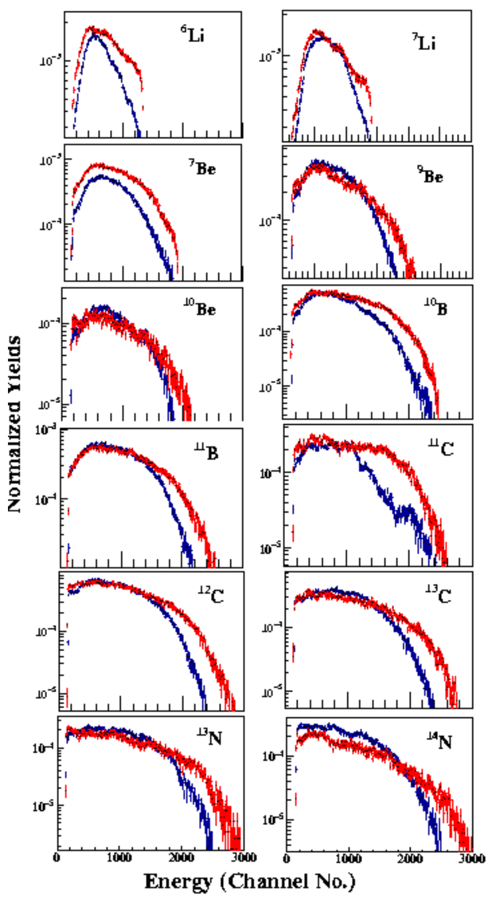

Fig. 3: Energy distributions of the isotope of various fragments emitted in ^{16}O (343 MeV) + ^{58}Ni (red lines) and ^{20}Ne (363 MeV) + ^{56}Fe (blue lines) reactions at 30^0.

Data Analysis and Results

The energy distributions of the light charged particle (α) and the isotopes of intermediate mass fragments up to Z=7 have been shown in Fig.2 and Fig.3, respectively. The light particle emission (α-particle) was found to be dominated in ^{16}O + ^{58}Ni reaction compared to ^{20}Ne + ^{56}Fe reaction (see Fig.2). It may be due to the composite form in ^{16}O + ^{58}Ni reaction more close to the α-cluster like. It has also been observed that as the neutron numbers in the isotopes of a fragment increases, the yields, particularly at low energy, was found to be dominated in ^{20}Ne (363 MeV) + ^{56}Fe (black solid lines) compared to that of the ^{16}O (343 MeV) + ^{58}Ni (red solid lines) reactions (see in Fig.3). This may be due to the composite formed in ^{20}Ne + ^{56}Fe reaction is more neutron-rich compared to ^{16}O + ^{58}Ni reaction. The above information also qualitatively implies the signature of isospin equilibrium prior to the fragmentation of the composites. Further data analysis is in progress to conclude more clearly.

In summary, fragments emission mechanism has been studied using the ^{16}O + ^{58}Ni and ^{20}Ne + ^{56}Fe reactions at high excitation energy. From the preliminary data analysis, it has been observed that the fragments are most likely emitted from isospin equilibrium composites. More details data analysis is in progress and will be presented during the symposium.

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