

The effect of clusters on fragment emission mechanism

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Abstract. Fragment emission mechanism has been studied for the composites ^{24,25}Mg at same excitation energy (~54 MeV). The inclusive energy distributions of the emitted fragments (Li and Be isotopes) have been measured. It has been observed that the fragments were emitted from a fully energy relaxed composite. The measured yield ratios of the fragments for the two reactions were compared with the statistical model prediction of the same. It was found that unlike Li isotopes, statistical model calculation deviates substantially for the Be isotopes. The observed deviations were due to the boost in the yields whenever there was a known alpha cluster nucleus, either ¹⁶O or ¹⁸O, as the complementary fragment of the binary decay.

1. Introduction

The presence of cluster structure in nuclei plays a significant role on the fragment emission mechanism for light composite systems, in particular, this would lead to an excess production of nuclei with predominant cluster structure with respect to the prediction of the statistical model. Recently, Morelli et al. [1], have observed some residual deviations from the statistical behaviour in two specific exit channels (carbon with 3 α 's and oxygen with 2 α 's channels) for the reaction ¹²C + ¹²C at beam energy of 95 MeV, which have tentatively been assigned due to the presence of direct reactions and/or α -clustering effects. Anomalously high branching ratios with respect to the statistical model calculation for these channels have also been observed [1] for the same system. Nevertheless, it is interesting to investigate the signature of cluster-correlation in dissipative binary decay of the same composite system as well as the effect of addition of one valence neutron to the same composite.

2. Experimental Details

The experiment has been carried out at BARC-TIFR Pelletron-Linac facility, Mumbai, using 80 MeV ¹²C and 78.5 MeV ¹³C ion beams on ¹²C target. We used two telescopes, each consisting of ΔE (50 μ m) single sided strip detector (SSSD), E (1mm) double sided silicon strip detector (DSSD) and backed by four CsI(Tl) detectors, each of thickness 6 cm. The inclusive energy distributions for various fragments (^{6,7}Li, ^{7,9}Be) have been measured in the angular range of 14°



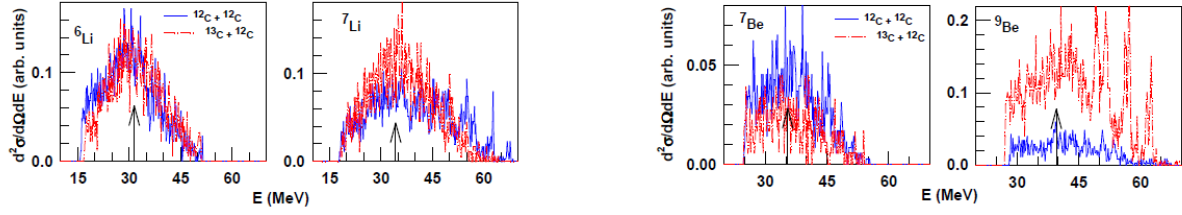


Figure 1. (Color online) (Left) Normalized energy distributions of Li isotopes in two reactions at $\theta_{lab} \sim 15^\circ$. Arrows indicate the mean energies of the fragments predicted by Viola systematics(see text). (Right) Same as Left for Be isotopes.

to 36° in the laboratory. The ^8Be spectra were reconstructed from 2α correlation data obtained from the telescopes.

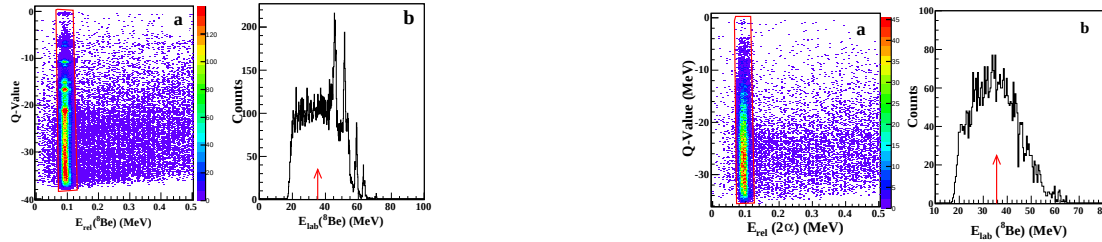


Figure 2. (Color online)(Left)(a)2-d plot between relative energy of 2α and binary beak up Q-value for the $^{12}\text{C} + ^{12}\text{C}$ reaction; (b)typical energy spectrum of ^8Be at 20° . Arrow indicates the mean energy of the fragment predicted by Viola systematics(see text). (Right)Same as Left for the $^{13}\text{C} + ^{12}\text{C}$ reaction.

3. Results and discussion

The normalized energy distributions of different isotopes of Li and Be fragments obtained in the reactions $^{12}\text{C} + ^{12}\text{C}$ (blue solid line) and $^{13}\text{C} + ^{12}\text{C}$ (red dash-dotted line) have been shown in Figure 1 except for ^8Be which is unstable and decays into 2α instantaneously. The ^8Be spectra was reconstructed from the measured α - α correlated data for all detected events and the corresponding Q-value was calculated assuming two body reaction and then plotted, as shown in Figure 2(Left)(a) and (Right)(a) for the reactions $^{12}\text{C} + ^{12}\text{C}$ and $^{13}\text{C} + ^{12}\text{C}$, respectively. The ground state energy spectrum of ^8Be has been obtained by gating on the correlation plots (as shown by red rectangular boxes in Figure 2) and were shown in Figure 2(Left)(b) and (Right)(b). Apart from some sharp transfer channel peaks at high energy ends, the energy distributions for all the fragments (Li and Be) are nearly Gaussian in shape, and their centroid are at the expected kinetic energies for the fission fragments as predicted by the Viola systematics (with correction by corresponding asymmetry factors) [2] (shown by arrows in respective Figures). This indicates that, in all cases, the fragments are emitted from a fully energy relaxed composite as expected for statistical decay of a compound nucleus. The angular distributions of the fragments in centre of mass frame have been shown in Figure 3 and are found to follow $\sim 1/\sin \theta_{cm}$ dependence (shown by solid lines in Figure 3) which further confirms that these fragments have been emitted from a fully energy equilibrated system. The ratios $[R^{exp(Th)} = (Y_{tot}(^{13}\text{C} + ^{12}\text{C})/Y_{tot}(^{12}\text{C} + ^{12}\text{C}))^{exp(Th)}]$ of yields of each fragment in the two reactions have been compared with the statistical model (CASCADE) [3] prediction for the same as shown in the Figure 4. It is seen that CASCADE predicts quite well for the $^6,^7\text{Li}$, but it under predicts for $^7,^9\text{Be}$ and over predicts for ^8Be . This

anomalous behaviour can be attributed to the effect of cluster correlation in fragment emission mechanism. In the case of emission of ${}^6,{}^7\text{Li}$, the complementary binary reaction products are any of the ${}^{17,18,19}\text{F}$ isotopes which are not known to have any pronounced cluster structure and so the decay is statistical in nature. On the other hand, the emission of any of ${}^7,{}^8,{}^9\text{Be}$ fragments is associated with the emission of one of the isotopes of oxygen (${}^{15-18}\text{O}$) as complementary fragment in the exit channel. Among them ${}^{16}\text{O}$ is a well-known alpha-cluster nucleus and the cluster structure of ${}^{18}\text{O}$ has also been fairly well established [4, 5, 6]. Therefore, yield of ${}^7\text{Be}$ in the ${}^{13}\text{C} + {}^{12}\text{C}$ reaction is expected to be higher than the corresponding statistical model prediction if cluster correlation due to ${}^{18}\text{O}$ contributes to the yield. This additional contribution will not be there in the case of ${}^{12}\text{C} + {}^{12}\text{C}$ reaction as the complementary fragment is ${}^{17}\text{O}$. Similarly the yield of ${}^8\text{Be}$ and ${}^9\text{Be}$ is associated with the emission of ${}^{16}\text{O}$ in the reaction channels ${}^{12}\text{C} + {}^{12}\text{C}$ and ${}^{13}\text{C} + {}^{12}\text{C}$ respectively. Clearly the effect of cluster correlation due to ${}^{16}\text{O}$ will boost up the yield of the respective decay channels over the statistical emission. This explains the observed trend in Figure 4.

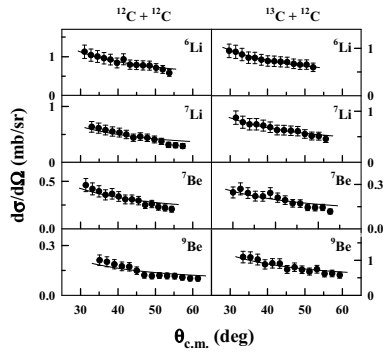


Figure 3. The centre of mass(cm) angular distribution of Li and Be isotopes for ${}^{12,13}\text{C} + {}^{12}\text{C}$ reactions. The solid lines correspond to $d\sigma/d\Omega \sim 1/\sin \theta_{cm}$ fit to the data.

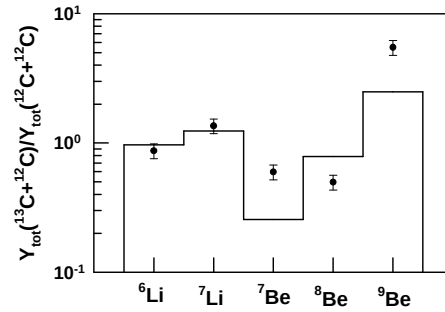


Figure 4. Ratio of fragment yields in ${}^{13,12}\text{C} + {}^{12}\text{C}$ reactions. Solid circles represent the data and the histogram shows the corresponding statistical model prediction.

4. Conclusions

The fragment emission mechanism have been studied in ${}^{13,12}\text{C} + {}^{12}\text{C}$ reactions. The relative yields of the isotopes of Li and Be emitted from fully energy relaxed composites ${}^{24,25}\text{Mg}^*$ were compared with statistical model prediction. Statistical model prediction agreed well with experimental results for ${}^6,{}^7\text{Li}$, but deviated significantly for ${}^7,{}^8,{}^9\text{Be}$. This was due to enhancement in yields for these fragments when the complementary fragments in the exit channel were either of ${}^{16,18}\text{O}$ isotopes, both being alpha cluster nuclei.

References

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