LIMITATIONS TO FUSION IN $^{16}O + ^{12}C$ AT 20 MeV/A

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Fusion cross sections (σ_f) for light heavy ions ($A_p+A_T<30$) at energies up to 18 MeV/A have been the subject of intense investigation over the last few years [1]. The particle spectra seem to arise mainly from complete fusion and direct reaction mechanisms [2]. Here, we present data from $^{16}O+^{12}C$ reactions measured at E_i= 20 MeV/A which clearly deviate from this systematics, giving evidence for important contributions from a mechanism other than the compound nucleus or direct reactions.

The experiment was performed using the ^{16}O E_i= 315 MeV beam from the 88-inch cyclotron at the Lawrence Berkeley Laboratory, to bombard a self-supporting ^{12}C target $100\mu g/cm^2$ thick. Angular distributions ($5°<\Theta_l<25°$) of outgoing reaction products (Z= 3-10) were measured and identified using a standard solid state telescope technique.

In Fig.1 we present typical energy spectra measured at Θ_l=7° for Z= 6-9 particles. These spectra are qualitatively similar to those observed at lower energies, in as much as they show two main components. However, the low outgoing energy groups, which we shall name here "quasi fusion", have their maxima at a fixed energy per nucleon $\bar{E}_{qf}\sim 10$ MeV/A corresponding to a velocity considerably higher than that expected [2] for complete fusion residues ($V_{CF}=\sqrt{2(16+12)E_{CF}}$). To further demonstrate this inconsistency, in Fig.1 we include the result of Monte Carlo Hauser-Feshbach calculations [3] (histograms) which are generally accepted [4] as a test for the occurrence of an equilibrated complete compound nucleus. The clear disagreement between these predictions and the data represent a strong indication for the dominance of a different process.

A number of simple conclusions may be drawn from these observations: a) a fixed $\bar{E}_{qf}$ value indicates a common origen for these components; b) their presence in the fluor spectra suggest the formation of a system heavier than the projectile; c) the values of $\bar{E}_{qf}>\bar{E}_{CF}/A$ =6.4 MeV/A imply that the quasi fused system has a "participant ratio" N_P/N_T (projectile

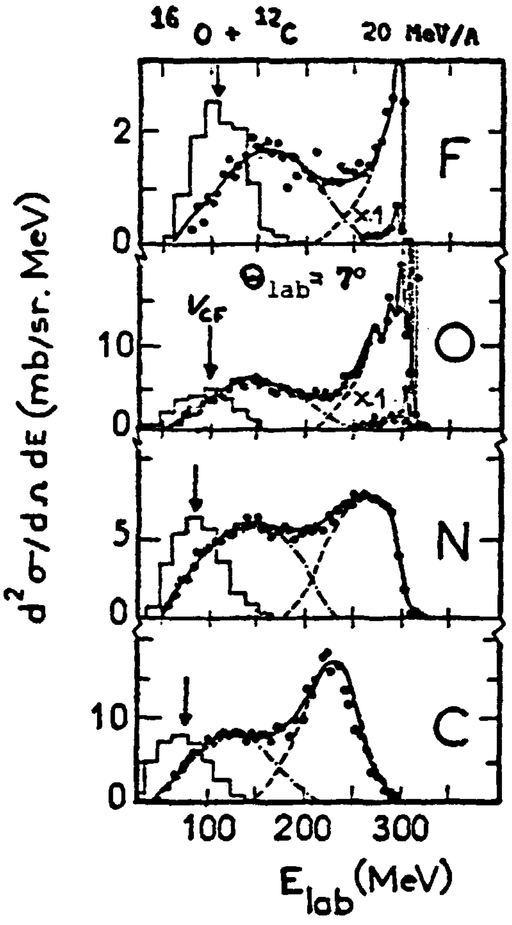

Fig.1: Energy spectra for Z=6-9 reaction products. Dashed lines illustrate the way high and low energy components were unfolded. Arrows V_{CF} show the position predicted for the maxima of complete fusion events, and histograms are compound nucleus-evaporation calculations.

nucleons/target nucleons) larger than 16/12. In fact, if energy losses are ignored, $\bar{E}_{qf}$= 10 MeV/A requires $N_P/N_T \geq 2.5$, i.e. $N_T \leq 6$, and therefore, $A_{qf}=N_P+N_T \leq 22$; d) the smooth isotope distribution, with Z=6 as the most probable residue is consistent with the formation of an equilibrated highly-excited quasi fused system. Through Monte Carlo calculations using a method similar to that suggested by Dayras et al.[5]), we estimate that the mass of the primary quasi fused system associated with the Z=6 group is indeed $A_{qf}=22\pm2$.

A value for σ_{qf} has been estimated by subtracting out the direct component in the spectra. For this purpose we deduced the shape of the quasi fusion group from observations at large angles, where contributions from the direct group are small. To account for unobserved yields we used the predictions from the evaporation calculations [3]). In this way, σ_{qf}= 600$\pm$100 mb is obtained. This value, though well within the predictions of Bass [6]) for σ_f, which approximately reproduces observations at lower energies, correspond to a sharp cutoff critical angular momentum J_f= 29 ħ, equal to the liquid drop limit [7]) prediction J_f^{LDL}= 28.7 ħ. Thus, we conclude that complete fusion evolves into quasi fusion due to angular momentum limitations.

The $N_P/N_T > 16/12$ condition, implying a target to projectile mass flow, helps in ruling out a standard deep inelastic interpretation. Also a direct α-pick up picture, which fulfills all kinematic restrictions, would require a disproportionally large cross section (600 mb) compared to the 200 mb observed for the α-transfer channel. Angular momentum limitations have lead to the "massive transfer" [8]) (incomplete fusion) mechanism observed in systems involving heavier targets. However, $N_P/N_T > 16/12$ means that a "massive pick up" would be a more appropiate interpretation for our data. It is interesting that the sum rule model of Wilczynski et al.[9]) predicts important "pick up" components for incomplete fusion channels at high incident energies.

The occurrence of highly excited sources moving with an anergy intermediate between that of the beam and that of the compound nucleus is a common feature of reactions at higher energies.[10] In fact, they have been reported[11]) for ^{16}O-induced reactions on heavy targets at E_i = 20 MeV/A. Even though at this moment a relation between these observations and our quasi fusion groups is not clear, they undoubtedly represent an interesting possibility.

We acknowledge A.Dacal and A.Galindo from UNAM, México, R.Legrain, J. Mahoney, M.Murphy, W.D.M.Rae and T.J.M.Symons from L.B.L. for their help during the experiment, and Prof.B.G.Harvey for his hospitality.

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