E1-E2 contributions in $^{12}C(\alpha,\gamma)^{16}O$ reaction

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Introduction

For direct capture reactions, Coulomb Dissociation has long been an important tool to study the breakup of nuclei specially in the cases of charged particles in the final state. Several reactions have been put to test under this technique to understand the formation of elements and structure of the nuclei, more so to explain stellar environments. CD as an indirect method, offers some advantages over other methods in that it allows breakup reactions to be carried out even at higher energies with large cross sections for the desired observables. As the beam energies are higher, the detection of the outgoing fragments emerging with higher velocities becomes easier. Also, sufficient kinematical quantities make it very precise and studies at low relative energies is not unsuited. Nevertheless, one must ensure that the reaction should have a negligible nuclear contribution or is Coulomb dominated, a facet usually taken care of when the scattering occurs at extremely forward angles. In CD, only a single multipole transition (*E1, E2, M2,...*) contributes to the cross section significantly, as is clear by the equation,

$$\frac{d\sigma}{dE_{rel}} = \frac{1}{E_\gamma}\sum_\lambda \sigma^{\pi\lambda} n_\gamma \qquad (1)$$

where n_γ is the virtual photon number. Furthermore, higher order effects must be taken care of like in any other first order theory.

Theoretical framework

We intend to apply it to study the $^{12}C(\alpha,\gamma)^{16}O$. The radiative capture reaction $^{12}C(\alpha,\gamma)^{16}O$, is considered to be very important for the helium burning stage of a star as it not only predicts the C/O ratio and paves a way for heavier element formation, but also helps to predict the future of massive stars as to whether they will undergo a supernova explosion to manifest into a neutron star or a black hole. Although on one hand a large cross section for this radiative capture can point towards the formation of heavier elements, on the other hand, a small cross section may refer to a breakup to form the lighter ones [1]. But because of the small cross section of the reaction $^{16}O(\alpha,\gamma)^{20}Ne$, consumption of ^{16}O by another α capture is very slow, explaining the abundance of ^{16}O in nature.

Although the studies have shown that it is favoured by an *E2* transition, an *E1* component contribution cannot be ruled out. Experiments have revealed that indeed, *E1-E2* interference terms should play an important role in explaining the data and must be included [2].

Results and Discussion

As a preliminary calculation, we have applied the first order semi-classical theory [3] to $^{12}C(\alpha,\gamma)^{16}O$ and studied its cross sectional dependence on *E1,E2* transitions. The ^{16}O projectile was bombarded on ^{208}Pb target at a beam energy of 100 MeV/u. The cross sectional variation due to the *E2* transition is interesting due to the $J^\pi = 2^+$ at a sharp E_{Res} = 2.68 MeV. However, closer inspection reveals that even an individual *E1* component is present due to the $J^\pi = 1^-$ resonance at 2.40 MeV. Whether this interferes destructively or constructively with the *E2* contribution remains to be found out.

Fig.1 shows the total Coulomb Dissociation cross section w.r.t. the relative energy, E_{rel} of the outgoing fragments ^{12}C and α. Fig. 2 shows the S-factor due to individual *E1* and

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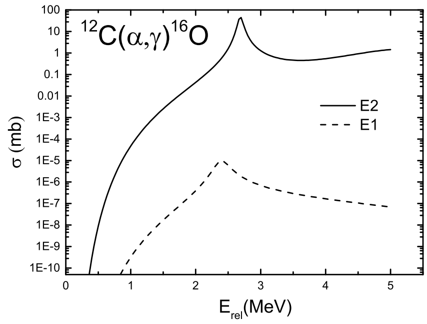

FIG. 1: Figure depicting the total cross section for the break up of ^{16}O on ^{208}Pb at a beam energy of 100 MeV/u to form ^{12}C and an α particle.

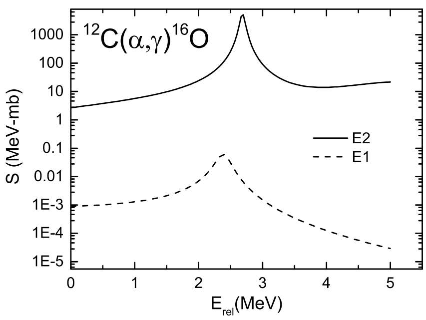

FIG. 2: Figure depicting the S-factor for the break up of ^{16}O on ^{208}Pb at a beam energy of 100 MeV/u to form ^{12}C and an α particle.

E2 contributions plotted w.r.t. the relative energy E_{rel} when ^{16}O is bombarded on ^{208}Pb at a beam energy of 100 MeV/u. The peaks are clearly visible and one can arguably say that the contribution of *E1* transitions is not negligible and must be accounted for.

As is clear from the graphs, there is a non negligible contribution due to the *E1* component coming from the 1^- state besides that from the *E2* component (from the 2^+ state), which evidently dominates.

Therefore, it will be interesting to see the interference effects of the two transitions for the cross sections and the S-factors and will be presented using the semi-classical theory for electromagnetic excitations of a compound nucleus [4].

References

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