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Analysis of Coulomb Breakup Reactions of ^{19}C on heavy Targets

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ABSTRACT

The Coulomb breakup reactions $^{181}Ta(^{19}C, ^{18}C+n)^{181}Ta$ and $^{208}Pb(^{19}C, ^{18}C+n)^{208}Pb$ has been investigated at 88AMeV and 67AMeV beam energies respectively within the theoretical framework of eikonal approximation with a motive to estimate the relative contribution of higher order multipole transitions, especially of electric quadrupole and dipole-quadrupole interference terms. The results so obtained reflect the finite contribution of electric quadrupole terms at higher relative energies while the dipole-quadrupole interference terms show their presence through longitudinal momentum distribution of core

Keywords: Keyword_1, Coulomb breakup, eikonal approximation, halo nuclei.

Introduction

Since last few decades halo nuclei have remains the subject of theoretical and experimental research. These nuclei exhibit a peculiar quantal structure due the combination of short range nuclear forces and low binding energy for valence nucleon and they are found at the edge of the valley of stability. These types of nuclei are short lived therefore they could not be investigated using traditional techniques.

Recently, the breakup of nuclei under the time varying electromagnetic field of heavy targets attracts more attention in conjugation with nuclear structure study. Secondly, the nuclear reactions involving halo nuclei are seem very crucial in understanding the problems relevant to nuclear astrophysics. Most of these problems are directly related with radiative capture reactions. But so far these reactions cannot be performed in the laboratory due to the unavailability of required environment. Fortunately in recent years several indirect methods like elastic scattering; Coulomb excitation and dissociation; transfer reactions; nuclear knockout reactions; quasifree reactions; charge-exchange reactions etc. have been developed to extract cross sections relevant to astrophysical processes[1]. Out of these, the Coulomb dissociation process is being used frequently for obtaining the capture cross section in connection to astrophysical problems. But unfortunately it is not free from bias because of the presence of the different contribution of electric quadrupole (E2) and dipole-quadrupole interference (E1-E2) terms[2, 3]. In order to obtain conclusive observations regarding the astrophysical problems one has to estimate the exact contribution of E2 and E1-E2 interference terms in the Coulomb breakup process. Therefore, in the present work the effects of E2 and E1-E2 interference terms have been investigated on the major observables of Coulomb breakup reaction like, cross section differential in relative energy and longitudinal momentum of the outgoing fragments.

Theoretical formalism

Depending on fully quantum or semi-classical approaches numbers of theoretical methods have been developed during past few decades. However, in the energy range of interest the eikonal approximation is the most convenient model to describe the Coulomb breakup process. The explicit expressions for differential Coulomb dissociation cross section in longitudinal momentum distribution and relative energy of core fragments corresponding to electric dipole, quadrupole and dipole-quadrupole interference terms are expressed as[3,4]

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$$\frac{d\pm_{E1}}{dq_z} = \int_{|q_z|}^{\infty} \frac{4Z_t^2 (Z_1^{eff})^2 \sim^2}{3¥^2 \quad ^2} ¶^2 I_{011}^2$$

$$\times\left[(K_1^2 - K_0^2)\{(1+2P_2) - (1-P_2)¥^2\} + \frac{2}{¶} K_0 K_1 (1-P_2)¥^2 \right]$$

$$\times q\, dq$$

$$\frac{d\pm_{E2}}{dq_z} = \int_{|q_z|}^{\infty} \frac{Z_t^2 (Z_2^{eff})^2 \sim^2}{105\,¥^2 \quad ^4} \left(\frac{µ}{c}\right)^2 ¶^2 I_{022}^2 \times$$

$$\left[\frac{4}{¶^2} K_1^2 (7 - 10P_2 + 3P_4) + (K_1^2 - K_0^2)(28 + 20P_2 + 57P_4) \right.$$

$$\left. + (7 + 5P_2 - 12P_4)¥^2 (2 - \quad ^2)^2 \left(\frac{2}{¶} K_0 K_1 - (K_1^2 - K_0^2) \right) \right] q\, dq$$

$$\frac{d\pm_{E1-E2}}{dq_z} = \int_{|q_z|}^{\infty} \frac{4Z_t^2 Z_1^{eff} Z_2^{eff} \sim^2}{5¥^2 \quad ^3} \left(\frac{µ}{c}\right) ¶^2 I_{011} I_{022}$$

$$\times \left[(K_1^2 - K_0^2)(2P_1 + 3P_3) + [\frac{2}{¶} K_0 K_1 - (K_1^2 - K_0^2)](P_1 - P_3)¥^2 (2 - \quad ^2) \right]$$

$$\times \quad q dq$$

$$\frac{d\pm_{E1}}{dE_{rel}} = \int_0^{®} \frac{4Z_t^2 (Z_1^{eff})^2 \sim^2}{3¥^2 \quad ^2} ¶^2 I_{011}^2$$

$$\times\left[(K_1^2 - K_0^2)\{(1+2P_2) - (1-P_2)¥^2\} + \frac{2}{¶} K_0 K_1 (1-P_2)¥^2 \right]$$

$$\times \sqrt{2E_{rel}\left(\frac{«}{\hbar^2}\right)^3} \; \sin ¯ \, d¯$$

$$\frac{d\pm_{E2}}{dE_{rel}} = \int_{|q_z|}^{\infty} \frac{Z_t^2 (Z_2^{eff})^2 \sim^2}{105¥^2 \quad ^4} \left(\frac{µ}{c}\right)^2 ¶^2 I_{022}^2 \left[\frac{4}{¶^2} K_1^2 (7 - 10P_2 + 3P_4) \right.$$

$$+ \; (K_1^2 - K_0^2)(28 + 20P_2 + 57P_4) + (7 + 5P_2 - 12P_4)¥^2 (2 - \quad ^2)^2$$

$$\times \left. \left(\frac{2}{¶} K_0 K_1 - (K_1^2 - K_0^2) \right) \right] \times \sqrt{2E_{rel}\left(\frac{«}{\hbar^2}\right)^3} \; \sin ¯ \, d¯$$

$$\frac{d\pm_{E1-E2}}{dE_{rel}} = \int_{|q_z|}^{\infty} \frac{4Z_t^2 Z_1^{eff} Z_2^{eff} \sim^2}{5¥^2 \quad ^3} \left(\frac{µ}{c}\right) ¶^2 I_{011} I_{022} \times$$

$$\left[(K_1^2 - K_0^2)(2P_1 + 3P_3) + [\frac{2}{¶} K_0 K_1 - (K_1^2 - K_0^2)](P_1 - P_3)¥^2 (2 - \quad ^2) \right]$$

$$\times \sqrt{2E_{rel}\left(\frac{«}{\hbar^2}\right)^3} \; \sin ¯ \, d¯$$

Results and Discussions

For performing the numerical calculations corresponding to different observables of Coulomb breakup process the radial part of the core-nucleon relative motion wave function is another important ingredient. It has been generated by solving the radial part of Schrodinger equation in Woods-Saxon potential. The strength of the potential has been determined to reproduce ground state binding energy of ^{19}C [0.530MeV] and the so obtained value is 73.5MeV. The range and diffuseness parameters are tuned locally at 2.33fm and 0.55fm respectively.

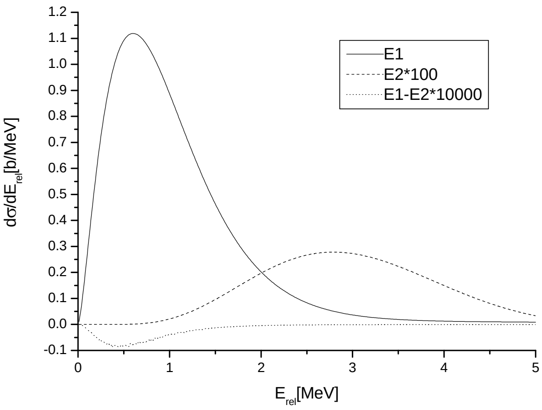

Figure 1 Relative energy spectrum of ^{18}C and n emerging out from the breakup of ^{19}C on lead target at 67AMeV beam energy. The solid line gives the E1 contribution only while dashed and dotted lines represents the contribution of E2 and E1-E2 interference terms respectively

Using these parameters the results so obtained are presented in figs. 1 & 2. In figure 1 the relative energy spectrum of fragments emitted in the Coulomb breakup of ^{19}C on lead target at beam energy 67AMeV has been presented. Here we have plotted results corresponding to different transitions like E1, E2, and E1-E2. The results obtained for E1 term are dominating while the results obtained for E2 and E1-E2 are multiplied by 100 and 10000 for the sake of clear comparisons. Further the higher transitions terms start contributing at higher energy and their contributions may be neglected at low relative energy. In figure 2 it has been shown that the inclusion of E1-E2 interference terms introduce a small asymmetry in the spectrum of longitudinal momentum distribution.

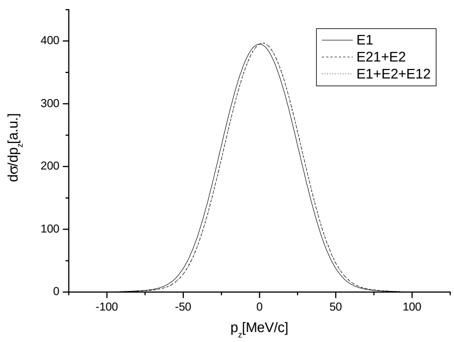

Figure 2. Longitudinal momentum distribution of core fragments emitted in the breakup of ^{19}C on Ta target at 88AMeV. The solid lines depicts the results obtained corresponding to dipole contribution(E1) only. The dotted line has been obtained after the inclusion of contribution offered by quadrupole (E2) and E1-E2 interference terms respectively.

Conclusions

In summary, the reactions $^{181}Ta(^{19}C, ^{18}C+n)^{181}Ta$ and $^{208}Pb(^{19}C, ^{18}C+n)^{208}Pb$ has been investigated at different beam energies for estimating the relative contributions of E1, E2 and E1-E2 transitions, which is essential for obtaining the structural and astrophysical information through Coulomb breakup method. The E2 and E1-E2 transitions show their presence at higher relative energies. Therefore, it becomes more important to estimate the exact contribution of these higher order transitions. It has been clearly seen that E2 contribution can be estimated by relative energy spectrum while the longitudinal momentum distribution is the suitable observable for detecting and estimating the contribution of E1-E2 interference terms.

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