Neon -^{12}C reaction cross section at 240 MeV/nucleon

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Introduction

The physics of unstable neutron rich nuclei is a field of current interest in nuclear physics due to their exotic properties. Advancement in radioactive ion beam facilities has made it possible to perform numerous experiments to get information about the neutron halo, Borromean structure and neutron skin, which are some of the important problems related to these nuclei. The neutron halo structure is the most exciting feature of exotic nuclei, in which the density distribution of weakly bound valance neutrons is spatially extended far beyond the tightly bound nuclear core into the classically forbidden region, giving rise large matter radii.

The unstable nuclei with large number of neutrons [1] have drawn considerable attention for the study of exotic properties of such nuclei. In this connection Takechi *et al.* [2,3] have measured the reaction cross section (σ_r) of $^{20-32}$Ne by ^{12}C at 240 MeV/nucleon. It was noticed that the σ_r values for $^{22-32}$Ne show large enhancements beyond the systematic trend of stable nuclei [2]. Moreover, it was observed that σ_r for ^{31}Ne shows an abnormally large enhancement as compared to the neighboring Ne isotopes. This result for σ_r, together with the experimental value of one-neutron separation energy for ^{31}Ne, indicates that ^{31}Ne may be the heaviest one-neutron halo system.

Recently Chauhan *et al* [4] have studied the reaction cross section of Ne isotopes on ^{12}C at 240 MeV/nucleon within the framework of Glauber Model. Using the relativistic mean field (RMF) densities for the colliding nuclei, it was found that the results are in close agreement with the available experimental data except for ^{31}Ne, for which the extended neutron density distribution is found to play an important role in explaining the data, thereby supporting a halo structure in ^{31}Ne.

In the present work, we have calculated the reaction cross section of Ne isotopes on ^{12}C at 240 MeV/nucleon within the framework of Glauber Model, involving the oscillator model for the densities of the colliding nuclei. Our aim is to see how far the oscillator densities are suitable in explaining the said data, and what could be said about these densities in the light of the above mentioned results with RMF densities.

Formulation

Neglecting the effects of nuclear correlations, the elastic S matrix element S_{00} may be written as [4]

$$\mathbf{S_{00}} \approx (\mathbf{1} - \mathbf{\Gamma_{00}})^{\mathbf{AB}}, \qquad (1)$$

With

$$\mathbf{\Gamma_{00}} = \int \boldsymbol{\rho}_{\mathbf{A}}(\mathbf{r})\boldsymbol{\rho}_{\mathbf{B}}(\mathbf{r}')\mathbf{\Gamma_{NN}}(\mathbf{b} - \mathbf{s} + \mathbf{s}')\mathbf{drdr}', (2)$$

where A and B are the target and projectile mass numbers, respectively, $\mathbf{b}$ the impact parameter, $\mathbf{s}$ and $\mathbf{s}'$ are the projections of the target and projectile nucleon coordinates on the plane perpendicular to beam direction $\mathbf{k}$, and $\rho_A(\mathbf{r})$ and $\rho_B(\mathbf{r}')$ are the ground state (one-body) densities of the target and projectile nuclei, respectively. The quantity Γ_{NN} is related to the NN scattering amplitude (f_{NN}) as follows:

$$\mathbf{\Gamma_{NN}} = \frac{\mathbf{1}}{\mathbf{2\pi ik}} \int \mathbf{d^2q}\, \mathbf{exp}(-\mathbf{iq.b})\, \boldsymbol{f_{NN}}(\mathbf{q}) \qquad (3)$$

Here, it is to be noted that Eq. (1) has been modified to account for the distinction between protons and neutrons through different pp and pn amplitudes.

Results and discussion

We analyze the reaction cross section of Ne isotopes from ^{12}C at 240 MeV/nucleon using oscillator densities and compare the predictions with the experimental values and also with the results obtained using RMF densities [4]. The inputs needed in the theory are the elementary NN amplitude and the nuclear (one-body) densities. The (oscillator) matter densities of the colliding nuclei are obtained using the method given in Ref. [5].

The NN scattering amplitude is usually parametrized in the following form [6]:

$$f_{NN}(q) = \frac{ik\sigma}{4\pi}(1 - i\rho)\exp\left(\frac{-\beta q^2}{2}\right) \qquad (4)$$

where σ is the NN total cross section, ρ the ratio of the real to the imaginary parts of the forward NN amplitude and β is the slope parameter. The values of σ, β, and ρ at 240 MeV are taken from Ref. [7]. The results of such calculations are presented in Fig. 1, and the corresponding NN parameters are given in Table 1. It is found that the results with oscillator densities are comparable to those obtained with RMF densities [4]. This shows the relevance of oscillator densities in the present context. Thus, we conclude that oscillator densities find a place to use in the studies of nuclear reactions. Regarding the enhanced experimental value of σ_r for ^{31}Ne, it was already mentioned that the extended neutron density distribution is able to reproduce the data. Keeping this in mind, it is, therefore, expected that the similar consideration for the neutron density distribution may help in reproducing the data using oscillator density.

Table 1: NN amplitude parameters at 240 MeV

σ_{pp} (fm^2)	σ_{pn} (fm^2)	β_{pp} (fm^2)	β_{pn} (fm^2)	ρ_{pp}	ρ_{pn}
2.28	4.13	0.086	0.106	0.944	0.541

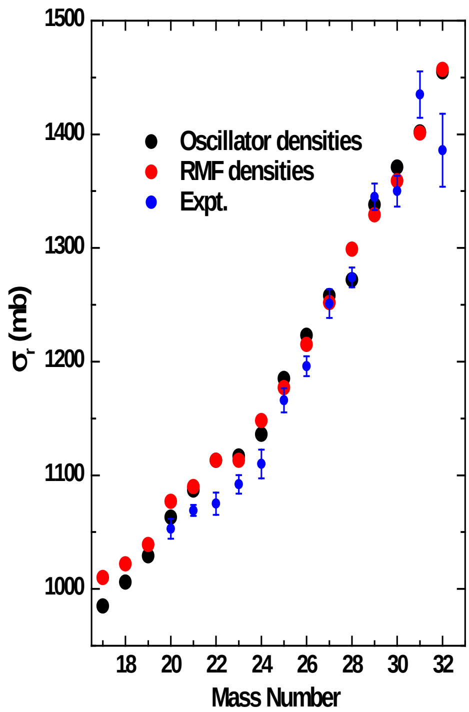

Fig. 1: Neon-^{12}C reaction cross section at 240MeV/nucleon

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