Microscopic coupled-channels calculations of nucleus-nucleus scattering including three-nucleon-force effects

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The total reaction cross sections are one of the most important quantities for nuclear data studies. For proton-nucleus scattering, a practical formula based on rich measured data was proposed by Carlson. On the other hand, for deuteronnucleus reactions, such systematic studies have not been performed. This is mainly because of the lack of experimental data in comparison with those for the protonnucleus reactions. The NASA's formula [1, 2, 3] for nucleus-nucleus total reaction cross sections can not reproduce the deuteron-nucleus total reaction cross sections.

In this work, we propose a more accurate formula for the deuteron-nucleus total reaction cross sections based on a theoretical calculation of deuteron scattering. We calculate the total reaction cross sections of deuteron, $\sigma_{\rm R}$, by the continuum discretized coupled-channels method (CDCC) [4] based on a microscopic three-body (p+n+A) reaction model. The p- and n-A potentials are calculated by the g-matrix folding model with the Melbourne g-matrix interaction and the target densities obtained by the Skyrme Hartree-Fock-Bogoliubov method. The reaction model has no free adjustable parameter and applicable to reactions at various deuteron incident energies E_d and with both stable and unstable nuclei. We have calculated $\sigma_{\rm R}$ for ^{9}Be, ^{12}C, ^{16}O, ^{28}Si, ^{40}Ca, ^{56}Fe, ^{58}Ni, ^{79}Se, ^{90}Zr, ^{93}Zr, ^{107}Pd, ^{116}Sn, ^{120}Sn, ^{135}Cs and ^{208}Pb at deuteron incident energies from 10 to 1000 MeV.

In the left panel of Fig. 1, we show the predicted $\sigma_{\rm R}$ for ^{12}C, ^{58}Ni, ^{120}Sn, and ^{208}Pb targets as a function of the deuteron incident energy. The predicted $\sigma_{\rm R}$ (thick lines) are almost consistent with those evaluated by a phenomenological deuteron optical potential up to 200 MeV and the measured data. On the other hand, the results of the NASA's formula (thin lines) cannot reproduce them, in particular, at low incident energies.

We construct a simple formula of $\sigma_{\rm R}$ up to 1 GeV, as a function of E_d, the target mass number A and its atomic number Z. The functional form and the parameters are given in Ref. [5]. The results of the simple formula well reproduce the results of CDCC as shown in the right panel in Fig. 1. This simple formula for $\sigma_{\rm R}$ is useful for simulation codes, such as the particle and heavy ion transport code system (PHITS) [6].

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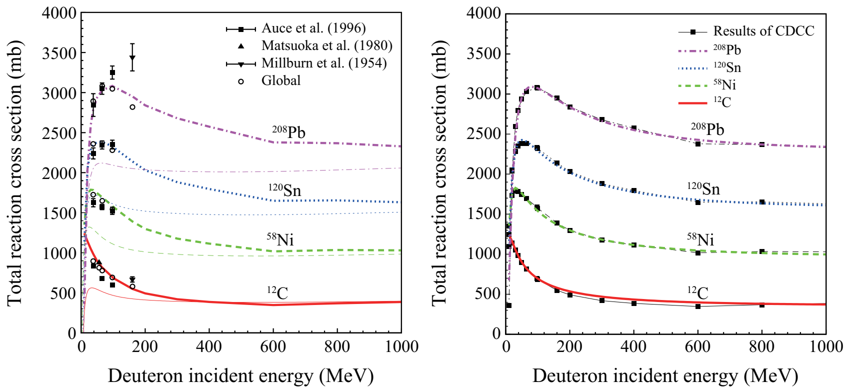

Figure 1: The predicted $\sigma_{\rm R}$ for ^{12}C, ^{58}Ni, ^{120}Sn, and ^{208}Pb targets as a function of the deuteron incident energy (left panel) and the fitted curves of the theoretical results (right panel). These figures are taken from Ref. [5].

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