Self-consistent microscopic description of neutron scattering by ^{16}O based on the continuum particle- vibration coupling method.

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Description of nucleon-nucleus (NA) elastic scattering based on the fundamental nucleon-nucleon (NN) interaction is one of the most challenging subjects of nuclear reaction studies, and is crucial for exploration of unstable nuclei, for which phenomenological optical potentials have not been established. In a recent paper [1], the microscopic continuum PVC (cPVC) method has been proposed. The cPVC method is based on the self-consistent microscopic HF and the continuum random-phase-approximation (RPA) [2] with the Skyrme effective interaction. In this framework, the microscopic nucleon optical potential is characterized by the nucleon self-energy corresponding to specific energy E in the asymptotic region of the $N + A$ system; E can be interpreted as the incident energy of the nucleon on the target nucleus A in the optical model picture.

In the cPVC framework, the scattering wave function of neutron $\Psi_{\rm PVC}(\boldsymbol{r}\sigma, \boldsymbol{k})$ from A, with the relative coordinate $\boldsymbol{r}$, the intrinsic coordinate σ due to the spin degrees of freedom, and the relative wave number $\boldsymbol{k}$ in the asymptotic region, is described by the following Lippmann-Schwinger equation

$$\begin{aligned}\Psi^{(+)}_{\rm PVC}(\boldsymbol{r}\sigma,\boldsymbol{k}) &= \phi_{\rm F}(\boldsymbol{r}\sigma,\boldsymbol{k})\\ &+\sum_{\sigma'\sigma''}\int\int d\boldsymbol{r}'d\boldsymbol{r}''G^{(+)}(\boldsymbol{r}\sigma,\boldsymbol{r}'\sigma';E)\left[v(\boldsymbol{r}'\sigma')\,\delta(\boldsymbol{r}'-\boldsymbol{r}'')\,\delta_{\sigma'\sigma''}+\Sigma(\boldsymbol{r}'\sigma',\boldsymbol{r}''\sigma'';E)\right]\phi_{\rm F}(\boldsymbol{r}''\sigma'',\boldsymbol{k}), \quad (1)\end{aligned}$$

where $\phi_{\rm F}$ denotes the neutron free wave and $v(\boldsymbol{r}'\sigma')$ is the HF one-body mean-field potential. The PVC Green function and the corresponding self-energy are denoted by $G^{(+)}(\boldsymbol{r}\sigma,\boldsymbol{r}'\sigma';E)$ and $\Sigma(\boldsymbol{r}'\sigma',\boldsymbol{r}''\sigma'';E)$, which are given by Eqs. (6) and (7) of Ref. [1], respectively. With this scattering wave function, one may evaluate the transition matrix(T matrix) in a straightforward manner.

In Ref. [3], the microscopic description of neutron scattering by ^{16}O below 30 MeV is carried out by means of the cPVC method with the Skyrme NN effective interaction. In the present calculation, we adopt the Skyrme NN effective interaction SkM*. For the cPVC calculation, as in Ref. [1], the orbital angular momentum cutoff for the unoccupied continuum states is set at $l_{\rm cut} = 7\hbar$, and we include RPA phonons associated with the multipolarities J^π of $2^+, 3^-, 4^+$, and 5^-, up to 60 MeV of the RPA excitation energy. In Fig.1, we compare the result of the reaction cross section $\sigma_{\rm R}(E)$ (solid black curve) with the experimental data [4]. (The dependence of $\sigma_{\rm R}(E)$ on the maximum multipolarity $J_{\rm max}$ is also shown.)

It should be remarkable achievement that the cPVC method explains about 85% of the experimental data on average for $\sigma_{\rm R}(E)$ which described only though particle-vibration coupling effects, i.e., with no imaginary part of an effective interaction.

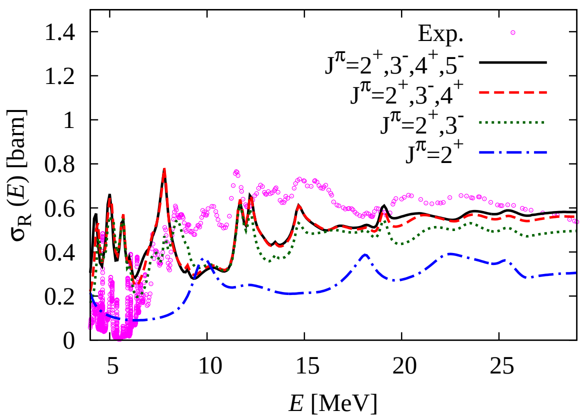

Figure 1: (Color online) Reaction cross section of neutron for ^{16}O. The solid, dashed, dotted, and dash-dotted lines correspond to the calculation with $J_{\rm max} = 5$, 4, 3, and 2, respectively. Experimental data are taken from Ref. [4].

Another remarkable feature of the cPVC result is the fragmentation of a single-particle resonant cross section. This results in good correspondence with some peaks seen at low energy, $E \leq 20$MeV, probably those due to the doorway states. Because 2p-1h configurations due to the particle-vibration coupling are taken into account in the cPVC method.

References

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