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 $\Psi_{\text{PVC}}(r, \sigma, k)$ from $A$, with the relative coordinate $r$, the
intrinsic coordinate $\sigma$ due to the spin degrees of freedom, and the relative wave number $k$ in the asymptotic region, is
described by the following Lippmann-Schwinger equation

\[
\Psi_{\text{PVC}}^{(t)}(r, \sigma, k) = \phi_F(r, \sigma, k) + \sum_{\sigma', \sigma''} \int dr' dr'' G^{(t)}(r, \sigma, r' \sigma'; E) [v(r' \sigma') \delta(r' - r'') \delta_{\sigma', \sigma''} + \Sigma(r' \sigma', r'' \sigma''; E)] \phi_F(r'' \sigma'', k),
\]

where $\phi_F$ denotes the neutron free wave and $v(r' \sigma')$ is the HF one-body mean-field potential. The PVC Green function
and the corresponding self-energy are denoted by $G^{(t)}(r, \sigma, r' \sigma'; E)$ and $\Sigma(r' \sigma', r'' \sigma''; E)$, 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 $l_{\text{cut}} = 7\hbar$, and we include RPA phonons associated with the multipoarities $J^\pi$
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 $\sigma_N(E)$ (solid black curve) with the experimental data [4]. (The dependence of $\sigma_N(E)$ on the maximum
multipolarity $J_{\text{max}}$ is also shown.)

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

Another remarkable feature of the cPVC result is the fragmentation of a single-particle resonant cross section. This
result 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

[4] Data retrieved from the National Nuclear Data Center, Brookhaven National Laboratory Online Data Service,