Self-consistent single-nucleon potential describing nuclear structure to intermediate-energy scattering

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Within the self-consistent mean-field or the Kohn-Sham (KS) scheme, the nuclear structure is described as if nucleons move independently under the single-particle (s.p.) potential, which is self-consistently produced from the effective interactions or energy-density functionals (EDFs). Most nuclear EDFs in the market have been developed phenomenologically, and their applicability is limited to negative and slightly positive energies. On the other hand, nuclear properties at finite temperature (FT), *e.g.*, the equation of state, are significant in astrophysical circumstances, *e.g.*, in the supernovae. As many-body correlations are unimportant at high temperatures, well-examined s.p. potential hopefully supplies reliable prediction of FT properties. The semi-realistic EDF M3Y-P6 [1] has been shown to predict magic numbers compatible with most experimental data [2], indicating the reliability of the s.p. potential at negative energies. Owing to its semi-realistic nature, it is of interest to apply this EDF to positive energies.

The s.p. potential at positive energy corresponds to the real part of the optical potential (OP) in the nucleon-nucleus (N-A) elastic scattering, often called folding potential. We find that M3Y-P6 gives self-consistent s.p. potential consistent with energy-dependence in the empirical OP [3]. The imaginary part of the OP represents the absorption effects, which originate from many-body correlations and vanish at thermal equilibrium. We apply the potential with M3Y-P6 on top of the KS wave-functions for the target nuclei to the N-A elastic scattering, supplemented by the empirical imaginary part [4]. The non-locality of the folding potential is explicitly taken into account via the SIDES code [5], without depending on the incident energy. Then the N-A cross sections are reasonably well up to $\approx 80\,\mathrm{MeV}$ [3]. This result indicates that a s.p. potential is obtained in a consistent framework with a single EDF and well examined in this wide energy range. Its application may supply a reasonable description of nuclear properties at FT ($T \lesssim 30\,\mathrm{MeV}$), which may be regarded as the FT KS scheme for nuclear systems.

References

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