CAN WE OBTAIN NUCLEAR BINDING AND DEFORMATION ENERGIES IN A SELFCONSISTENT WAY WITHOUT DOING HARTREE-FOCK CALCULATIONS?

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The validity of the shell-correction (SC) method /1,2/ has been tested extensively in constrained Hartree-Fock (HF) calculations using effective interactions of the Skyrme type /3,4/. The total HF energy is expanded around the average part of the selfconsistent density matrix \( \rho \) (thus writing \( E_{HF}[\rho] = E_{HF}[\rho] + \delta_4 E + \delta_5 E \)).

\[
E_{HF}[\rho] = E_{HF}[\rho] + \delta_4 E + \delta_5 E. \tag{1}
\]

Here \( E_{HF}[\rho] \) represents the average binding energy which is parametrized in the liquid drop model; \( \delta_4 E \) is the first order shell-correction defined in the usual way /1,2/ in terms of the eigenvalues of the averaged HF potential (which may be parametrized by the shell model potential). The term \( \delta_5 E \) contains contributions of second and higher orders in \( \delta_\rho \) and is neglected in the usual SC approach. It was shown numerically /3,4/ that the series (1) converges extremely well; the energy \( \delta_5 E \) is not larger than \(-1-3 \) MeV in medium and heavy nuclei. It was especially found /4/ that if \( \rho \) is iterated to selfconsistency, \( \delta_5 E \) is less than \(-0.6 \) MeV and practically constant as function of both deformation and nucleon numbers, even for nuclei as light as \( ^{16}_\text{O} \) and \( ^{40}_\text{Ca} \). This result provides a strong motivation for a method in which only the average binding energy and the average field are calculated selfconsistently with some effective interaction (and a constraint on the deformation), and the shell-correction is added as a perturbation, using the selfconsistent average field obtained in the first step. For the average self-consistency problem, we propose to use the extended Thomas-Fermi (ETF) model, in which the total energy for a given one-body potential \( V(r) \) is obtained directly in terms of \( V(r) \) and its derivatives /5/. Note that the pure TF approximation is not sufficient; the semiclassical corrections to it contribute up to \(-100 \) MeV in a heavy nucleus. In the Strutinsky averaging method one automatically includes these corrections. It has been checked /6/ that for realistic (spherical and deformed) Woods-Saxon potentials, including a spin-orbit part, the ETF energies agree with the Strutinsky averaged energies within \(-1-2 \) MeV. Instead of solving a differential equation for the density \( \rho(r) \), we iterate both \( V(r) \) and \( \rho(r) \) until selfconsistency is reached. Hereby an exponential tail is added to the semiclassical \( \rho(r) \) which is only defined inside the classically allowed region. The kinetic energy density is expanded in terms of \( \rho(r) \). We have recently shown /7/ that the average kinetic energy in a Woods-Saxon potential can be obtained from \( \rho(r) \) within \(-1-2 \) MeV, if also the next term after the so-called Weizsäcker term is added in the expansion of the kinetic energy density.

References.