The Nuclear Diffuseness as a Degree of Freedom*

W.D.Myers and W.J. Świątecki

In [1] we have investigated the response of the nuclear energy to changes in the neutron and proton surface diffusenesses using the Thomas-Fermi model. Algebraic expressions have been formulated for the energy cost of changing the two diffusenesses away from their equilibrium values. This will make it possible to generalize the macroscopic-microscopic calculations of nuclear masses and deformation energies by the inclusion of the neutron and proton diffusenesses as degrees of freedom (to be varied along with the shape degrees of freedom). One result, which is suggested by the relatively low cost in macroscopic energy of increasing the diffuseness of a heavy nucleus by 10% (about 4 MeV), is that super-heavy nuclei near $Z = 126$, $N = 184$ may have a fair chance to become stabilized by shell effects.

In macroscopic-microscopic approaches to extrapolations into the superheavy regime the nuclear mean field is parametrized as a shape-dependent Woods-Saxon or similar potential, in which the Strutinsky shell correction is then evaluated. In order to find the ground-state energy and shape of a nucleus the sum of the microscopic shell correction and a macroscopic energy is varied as a function of the shape degrees of freedom. In such variations the surface diffuseness is usually kept constant, but one may well ask how the result would change if, when locating the energy minimum, the diffuseness were to be treated as an additional degree of freedom, to be varied simultaneously with the shape degrees of freedom.

There have been indications as long ago as 1966 (See Fig. 4 in [2]), that an increased surface diffuseness would begin to favour the magic proton number Z=126 over 114. This possibility has been examined in the recent comprehensive study in [3], where macroscopic-microscopic extrapolations were confronted with self-consistent Hartree-Fock calculations.

The possibility of a reappearance of the magic proton number 126 would affect profoundly forthcoming searches for spherical superheavy nuclei, and it is extremely important to throw further light on this question by performing up-to-date macroscopic-microscopic calculations generalized to include the surface diffuseness degree of freedom. This should be done in parallel with further refinements of the Hartree-Fock calculations, aimed at eliminating ambiguities associated with different choices of the effective interaction.

In order to carry out a macroscopic-microscopic calculation with the diffuseness degree of freedom included, it is necessary to investigate the response to diffusenes of both the macroscopic and microscopic parts of the energy. The machinery for calculating the latter is already in place: simply recalculate the Strutinsky shell correction for a series of diffusenesses. For the former, we have combined the known response of the Coulomb energy to diffuseness with the response of the macroscopic surface-layer energy calculated using a reliable Thomas-Fermi model of nuclei fitted accurately to a wide range of nuclear properties [4]. (An early attempt to estimate the response of the macroscopic energy to variations of the surface diffuseness was made in [5].)

*Extracted from Ref. [1]

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