Deformation influence on cold fusion reactions

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Effects of target and projectile deformation on the shell corrections are calculated within the deformed two-center shell model [1, 2]. The deformed two center oscillator potential which assures equipotentiality on the surface of the two intesected nuclei reads:

$$V^{(r)}(\rho,z) = \left\{ \begin{array}{lll} V_1 = & \frac{1}{2}m_0\omega_{\rho_1}^2\rho^2 + \frac{1}{2}m_0\omega_{z_1}^2(z+z_1)^2 & ,v_1 \\ V_2 = & \frac{1}{2}m_0\omega_{\rho_2}^2\rho^2 + \frac{1}{2}m_0\omega_{z_2}^2(z-z_2)^2 & ,v_2 \end{array} \right. \tag{1}$$

where v_1 and v_2 are the space regions where the two potentials are acting. The frequencies are shape dependent, thus one obtains from volume conservation and mass dependency of ω the relations:

$$\begin{array}{lll} m_0\omega_{\rho_i}^2 = & (a_i/b_i)^{2/3}\cdot m_0\omega_{0i}^2 = & (a_i/b_i)^{2/3}\cdot 54.5/R_i^2 \\ m_0\omega_{zi}^2 = & (b_i/a_i)^{4/3}\cdot m_0\omega_{0i}^2 = & (b_i/a_i)^{4/3}\cdot 54.5/R_i^2 \end{array} \tag{2}$$

In this way the two center oscillator potential for fusion like shapes follows the changes of the two spheroidal partner deformations.

In order to find out each of the space regions v_1 and v_2, we rely on the assumption that the pass from V_1 to V_2 must be smooth; hence no abrupt cusp in the potential value has to exist between v_1 and v_2. If the two regions comply to this condition, they have to be bordered by the same surface. Such a surface is the solution of the following matching condition between $V_1(\rho,z)$ and $V_2(\rho,z)$:

$$V_1(\rho,z) = V_2(\rho,z) \tag{3}$$

Eq. (3) describes an ellipsoidal surface. On any of its points the two potentials, V_1 and V_2, match eachother.

The total Hamiltonian of the system is:

$$H = -\frac{\hbar^2}{2m_0}\Delta + V^{(r)}(\rho,z) + V_{\mathbf{\Omega s}} + V_{\mathbf{\Omega^2}} \tag{4}$$

where $V_{\mathbf{\Omega s}}$ and $V_{\mathbf{\Omega^2}}$ are the spin-orbit and the squared angular momentum interaction potentials.

The spin-orbit operator is calculated as usual using creation and anihilation components:

$$\mathbf{\Omega s} = \frac{1}{2}(\mathbf{\Omega}^+\mathbf{s}^- + \mathbf{\Omega}^-\mathbf{s}^+) + \mathbf{\Omega}_z\mathbf{s}_z \tag{5}$$

where:

$$\mathbf{\Omega}^+ = -e^{i\varphi}\left[\frac{\partial V^r(\rho,z)}{\partial\rho}\frac{\partial}{\partial z} - \frac{\partial V^r(\rho,z)}{\partial z}\frac{\partial}{\partial\rho} - \frac{i}{\rho}\frac{\partial V^r(\rho,z)}{\partial z}\frac{\partial}{\partial\varphi}\right]$$

$$\mathbf{\Omega}^- = e^{-i\varphi}\left[\frac{\partial V^r(\rho,z)}{\partial\rho}\frac{\partial}{\partial z} - \frac{\partial V^r(\rho,z)}{\partial z}\frac{\partial}{\partial\rho} + \frac{i}{\rho}\frac{\partial V^r(\rho,z)}{\partial z}\frac{\partial}{\partial\varphi}\right]$$

$$\mathbf{\Omega}_z = -\frac{i}{\rho}\frac{\partial V^r}{\partial\rho}\frac{\partial}{\partial\varphi} \tag{6}$$

In this way the angular momentum dependent operators are also shape-dependent. Details of calculation and matrix element formulae are given in [1, 3].

The superheavy synthesis reaction U+^{48}Ca $\rightarrow$ 112 has been analyzed for different isotopes of uranium spanning continuously the spheroidal target deformation. In Fig. 1 the level schemes (uppper plot) and the shell effects for protons $E^{(}_{shell}p)$ and total E_{shell} are drawn. Differences are visible for the higher energy levels. Until the last part of the overlapping almost no difference exists within the proton shell correction. Divergence in the curve behaviour appears at the end of the fusion process. The two branches in E_{shell} correspond to the two proton level scehme deformations of Z=112 (where the ratio of spheroid semiaxes is $\chi = 0.89$ and $\chi = 1$). The total shell correction E_{shell} follows the same behaviour slightly lowering the ^{232}U reaction shell correction in the first part of the process. Shell correction values less than those corresponding to sphere suggest a more deformed ground state for 112 isotopes than those taken into account here.

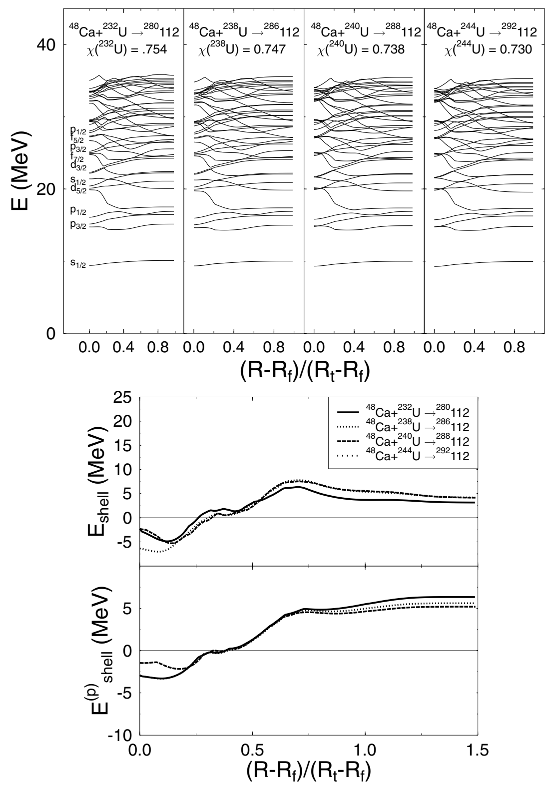

Figure 1: Target deformation effects on the level scheme (upper plot) and on the proton and total shell correction for four isotopic reactions in the synthesis of Z=112.

References

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