A study of Coulomb displacement energies for nuclides with A around 67*

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If one assumes that nuclear force is charge symmetric, Coulomb displacement energy (CDE) can be extracted as the binding energy difference of mirror nuclei [1]. CDEs play an important role in nuclear structure, like e.g., can be use to study deformation of nuclei [2]. Recent experiments provided a wealth of new data on nuclear masses of neutron-deficient nuclei, either measured for the first time or with significantly improved uncertainties [3]. With these mass data, experimental CDEs (ΔE_c) for the T=1/2 mirror nuclei up to A=73 in pf-shell can be mapped, as Fig. 1 shows.

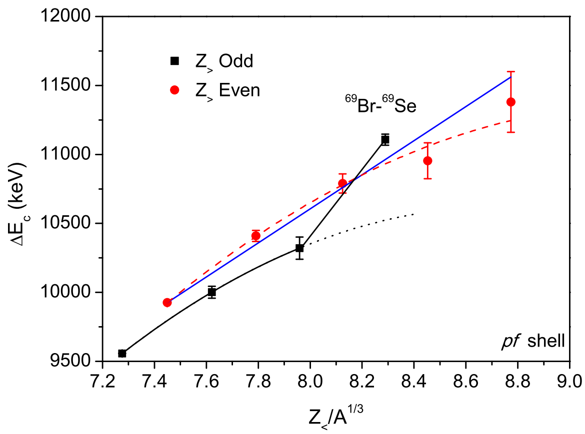

Figure 1: Coulomb displacement energy for the $T = 1/2$ mirror nuclei in the fp-shell as a function of $Z_</A^{1/3}$, labelled differently for odd-$Z_>$ and even-$Z_>$. ΔE_c for even-$Z_>$ were fitted by a linear function (solid line) and second order polynomial function (dashed line) of $Z_</A^{1/3}$, respectively. For odd-$Z_>$, the dotted line shows an expected tendency obtained by second order polynomial fitting.

For a homogeneously charged spherical nucleus, the CDEs can be fitted well by an empirical linear formula. However, it is well known that the deformation can lead to modifications of single-particle states and cause qualitative changes in the structure, and therefore can alter the linear dependence of CDE on $Z_</A^{1/3}$. If one assumes that a deformed nucleus has a quadrupole deformation, β, then the modified CDE, $\Delta E_c(\beta)$, can be estimated by the following expression [2],

$$\triangle E_c(\beta) \simeq \triangle E_c(0)\left[1 - \frac{4}{45}\beta^2\right] \qquad (1)$$

where $\Delta E_c(0)$ is the spherical CDE, which can be fitted by using the known spherical nuclei.

The notable difference from the spherical shells is that the CDE values in the fp-shell can not be fitted by a linear function of $Z_</A^{1/3}$, but show a slowing-down increase as $Z_</A^{1/3}$ increases [4]. The data are better fitted by a second order polynomial function as described by Eq. (1) with non-zero deformation parameters. This implies that spherical shape of nuclei starts to change at $Z_</A^{1/3} \sim 7.96$ (corresponding to $A = 65$ and $Z_> = 33$) and the quadrupole deformation β is developed for larger $Z_</A^{1/3}$ values. This is precisely the region where Hasegawa *et al.* [5] suggested, based on the study of the low-lying energy levels, that a spherical-to-deformed shape phase transition occurs along the $N \approx Z$ line.

Another feature seen in Fig. 1 is the staggering of the CDE values between the groups with odd-Z and even-Z. This so-called odd-even staggering is such that CDE with even-$Z_>$ are larger than the CDE with odd-$Z_>$. The occurrence of the odd-even staggering in CDE was first explained by Feenberg and Goertzel [6] as being due to the fact that the paired protons with antiparallel spins have a space-symmetric wave function in their relative coordinates and therefore repel each other stronger than the pairs with parallel spins. This strong Coulomb repulsion for systems with all protons paired leads to larger CDE values for even-$Z_>$. However, with the new data, as seen in Fig. 1, the data point for the ^{69}Br-^{69}Se mirror pair obviously departures from the staggering rule, and the regular trend of the odd-even staggering is thus destroyed. This is the first observation of this apparent anomaly, which has to be questioned theoretically on possible fundamental reasons as well as experimentally on possible systematic errors of the corresponding measurements [4].

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