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SUPERHEAVY ISLANDS OF NUCLEAR STABILITY

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The work by the Lund group has presently the primary aim of predicting the properties of possible islands of superheavy elements.

With this aim in mind we have improved on our previous calculations by studying the most critical problem involved, that of the extrapolation of the nuclear potential parameters (this problem is treated in the communication submitted by C. Gustafsson). Furthermore we have now also included in our study the problem of odd-A effects in the Z=114 region (see communication by G. Ohlén), effects of non-axial types of deformations (P. Möller), and effects of the ultimate development of a two-center-type of potential (T. Johansson).

The calculations have also been extended to the Z=164 region (see communications by R. Bengtsson), already studied by other authors. In this calculation the problem of the shell structure parameter extrapolation is additionally critical. To cast some light on the extrapolation a similar "extrapolation" is performed from the rare-earth region, where shell structure is treated as known, and into the Z=40-60 region immediately below, where shell structure in one case is treated as being entirely unknown. The contribution discussing the results in the region mentioned is submitted by I. Ragnarsson and appears under another section of this conference report.

Abstract

Superheavy islands of nuclear stability

Review of work in progress by the Lund group

by

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A. The shell model parameters of the Z = 114 region.

(Christer Gustafsson, conference participant)

The basis for the extrapolation of the parameters of the modified deformed oscillator model is considered. The rare-earth and actinide regions have been refitted as the $\vec{l}_t \cdot \vec{s}$ term in the potential is replaced by a term proportional $(\vec{p} \times \vec{\nabla} V) \cdot \vec{s}$. Optimal extrapolations and extrapolations corresponding to two limits representing minimal and maximal shell structure effects are considered. The half-lives are in gross agreement with those deduced by Nilsson, Tsang et al. Some measure of the limits of inaccuracy are provided by the alternative limiting cases of extrapolation.

B. Effects of odd-A masses in the Z = 114 region.

(Gunnar Ohlén)

Empirically, odd-A nuclei have longer fission half-lives than neighbouring even-even ones. This is due largely to the increase of barrier represented by the so-called specialisation energy. Separate potential-energy surfaces in the $(\varepsilon_2, \varepsilon_4)$ plan for each angular momentum and parity are calculated under the condition that the odd-particle has available solely orbitals of the angular momentum and parity given. Upper limits on alpha half-lives are computed under the condition that the half-life essentially equals that of the unhindered component populating the (exited) daughter state with intrinsic quantum numbers equal to those of the mother ground state.

C. Effects of the P_3 and P_5 deformations on the fission barriers of the superheavy elements.

(Peter Möller)

The effect of the P_3 and P_5 degrees of freedom on the barriers (computed by Nilsson, Tsang et al) for the Z = 114 region is investigated. It is found that the inner and dominant barrier is uneffected by these added degrees of freedom while the lower outer barrier is reduced by less than 1 MeV. The fission half-lives are thereby reduced by factors of less than 10 for $285 < A < 305$. Thus the factors of uncertainity due to other sources of error as, e.g. the insufficient knowledge of the shell structure parameters are several powers of ten larger (see A).

D. Extrapolations to the Z = 164 region.

(Ragnar Bengtsson)

From the calculations by Nilsson, Nix et al and others, the prominence of the gap at Z = 164 is conspicious for the set of nuclear parameters employed for $A \approx 300$. Furthermore, the size of the gap appears only weakly dependent on the value of A. It thus appears that the gap may persist to A = 400 - 500 when it becomes relevant. An extrapolation to the Z = 164 region has been attempted recently by J. Grumann, U. Mosel, B. Fink, and W. Greiner. Important changes in the results relative to these authors are noted. These are due to the employment of the Strutinsky liquid-drop renormalisation method. As a general conclusion it appears that calculations will have to be extended so as to include the gamma degree of freedom to be sufficiently extensive. Also the shell parameters extrapolations appear extensively hazardous (see E).

E. "Extrapolations" to the Z = 40 - 60 region of elements.

(Ingemar Ragnarsson)

As a test case for the method of shell parameter extrapolations employed in the superheavy region we have used the same prescriptions to treat the regions below the rare earth region where our shell parameters have been fitted. Of great interest are here the deformed regions connected with Z = 54-56, N = 66-72 and Z = 42-44, N = 62-70. In the latter region some g.s. oblate shapes are encountered. It appears that the linear extrapolation employed is somewhat insufficient in the latter region.

F. Two-center nuclear potential and the $(\bar{p}\times\bar{\nabla}V)^2$ term.

(Thomas Johansson)

Calculations have been in progress of the last three years in Lund to improve the nuclear potential at large fission distortions with an e^{-z^2/α^2} term added to the harmonic oscillator potential to generate a neck-in parameter. These are parallel to the calculations by Anderson and Dietrich and by Greiner et al, some preliminary results of which have already been published. It is found that, while the replacement of the l^{-2}-term by the $(\bar{p}\times\bar{\nabla}V)^2$-term in itself is a difficult procedure as the empirical single-particle level order is not reproduced at empirical ground state distortions, the neck-in term may improve the level sequence. The problem of a proper volume conservation and a generalization of the $\langle \vec{l}^2 \rangle_N$ term is as yet not satisfactorily taken care of in our calculations.