Limits of stability, formation mechanism and structure of shell-stabilzed heavy nuclei

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Recent experiments and theoretical calculations have shed new light on heavy nuclei that are stabilized by the shell-correction energy. This abstract describes results from experiments with Gammasphere and the Fragment Mass Analyzer at Argonne [1-2], and compares these results with those from recent self-consistent mean-field models. The experimental data provide information on: (i) the limits of stability as functions of spin and excitation energy; (ii) the fission barrier as a function of spin; (iii) the survival probability against fission of hot nobelium nuclei [from (i and ii)], which is critical for understanding the formation mechanism of superheavy nuclei; (iv) the importance of high partial waves in the synthesis of superheavy nuclei; (v) the moments of inertia of rotational bands in ^{253,254}No; and (vi) a neutron quasiparticle energy from ^{253}No. As an example, the first figure below shows a spectrum of the ground-state band of ^{254}No up to spin 20 and the entry distribution (in spin and excitation energy), which reveals that ^{254}No survives fission up to at least 22 hbar in spin and 8 MeV excitation energy and that the fission barrier above spin 10 hbar is at least 5 MeV. Clearly the entry distribution extends well beyond the blue shaded region, which denotes the stability limits of a rotating liquid drop, thereby graphically illustrating the addtional stability given by the shell-correction energy. Experiments at Jyväskylä, with RITU in combination with various Ge arrays and an electron spectrometer, have also revealed the properties of ^{252}No [3], as well as of ^{254}No.

Calculations have been performed in the framework of non-relativistic and relativistic self-consistent mean field theories (see, for example, [4-7]), as well as with the microscopic-macroscopic approach (by Sobiczewski *et al.*). For the self-consistent mean-field models, the heaviest nuclei provide an especially interesting test since the effective forces have been selected from fits to the bulk properties of "normal" lighter nuclei, where the binding comes predominantly from the liquid-drop term (from the viewpoint of the Strutinsky approach). In brief, the self-consistent models (i) provide good descriptions of the moments of inertia of ^{252,253,254}No, although details of the variation with A and spin are not fully described; (ii) suggest that the fission barrier remains large at high spin [4-5], in agreement with experimental entry distribution measurements; and (iii) reproduce many quasiparticle energies of deformed nuclei within 0.5 MeV, although there are systematic discrepancies of >1 MeV for certain classes of orbitals--results [6] with the NL1 and NL3 Lagrangians are given in the second figure below. Ref. [6] presented the first systematic test of the accuracy of self-consistent mean-field quasiparticle energies, by examining the known quasiparticle states in the transuranic nuclei ^{249}Bk and ^{249,251}Cf. (A similar test has been conducted in [7]). The third figure compares experimental and theoretical kinematic and dynamic moments of inertia, $J^{(1)}$ and $J^{(2)}$, for ^{252,254}No and for the 7/2$^+$[624] band in ^{253}No. The upper panel shows the results from experiment [1-3] and the lower panel presents results from the Skyrme Hartree-Fock Bogolubov model [7]. The magnitudes and general trends are reproduced by theory, but details, such as the variation with spin and mass, are not in perfect agreement, probably due to some imperfections in the energies of high-*j* single-particle orbitals.

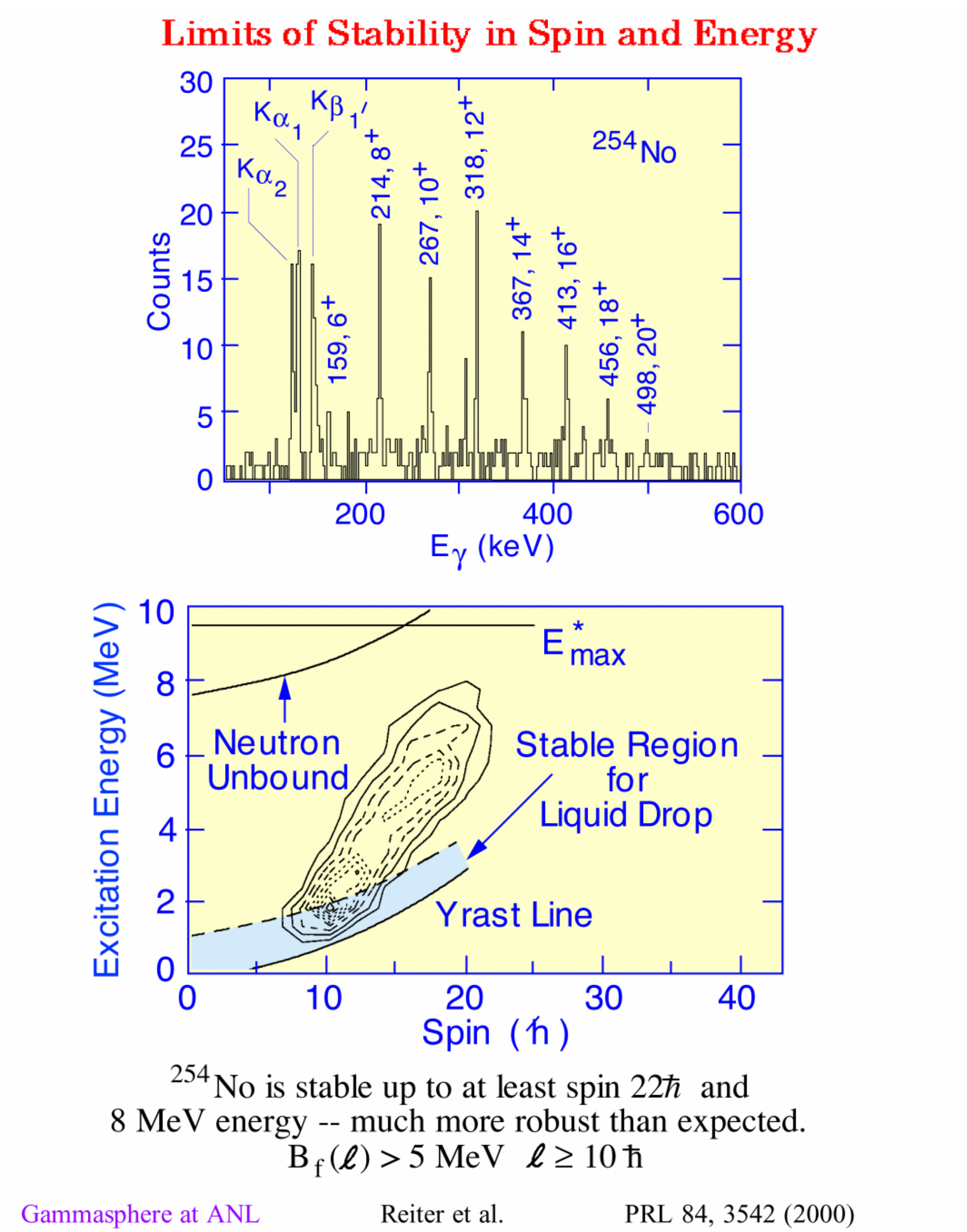

Figure 1.

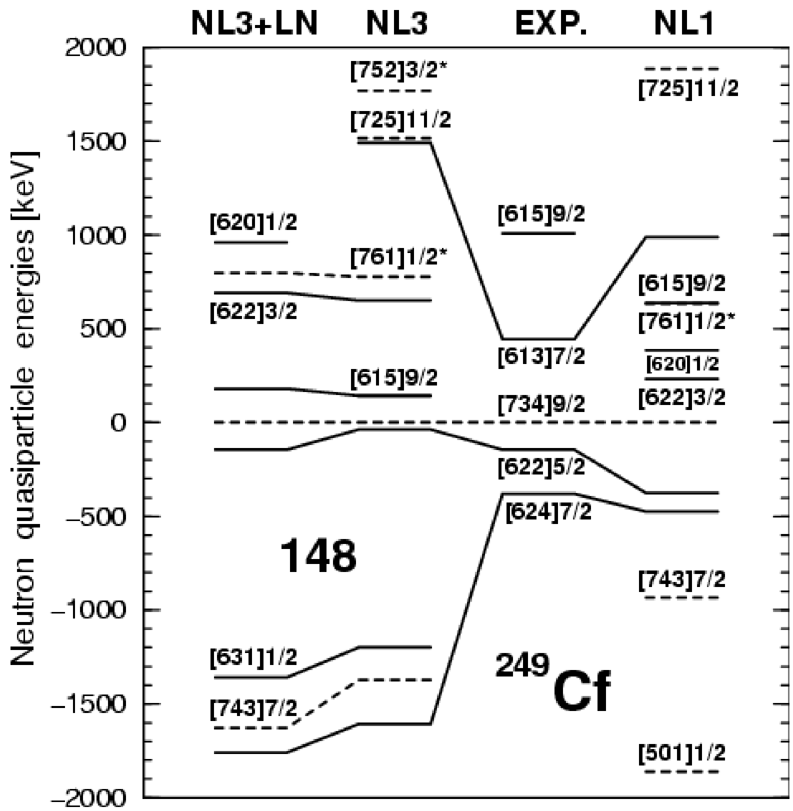

Figure 2.

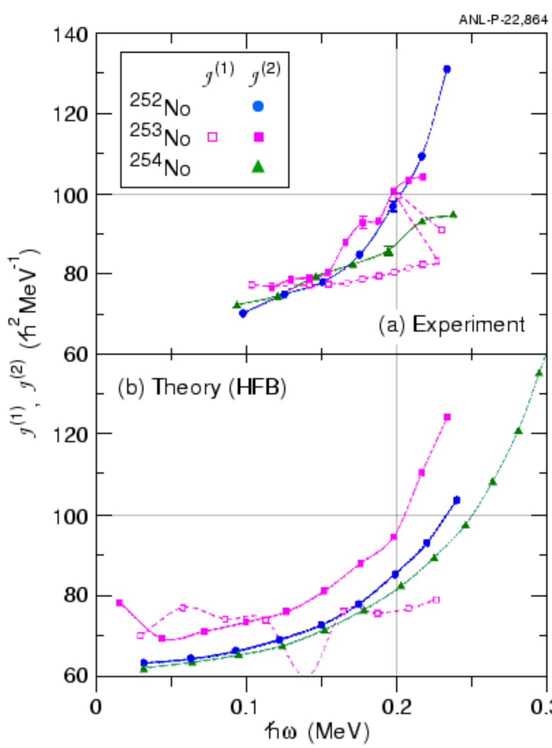

Figure 3.

Acknowledgements

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