Fission Hindrance in Odd-Mass Transuranium Nuclei*

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It had been realized already in early studies of nuclear fission, that partial fission half-lives of nuclei having odd proton and/or neutron numbers were considerably longer than those of even-even nuclei [1]. In this sense spontaneous fission of odd-mass and odd-odd nuclei was regarded as 'hindered'.

This phenomenom has been explained as the consequence of spin and parity conservation (see e.g. [2,3]). While in case of nucleon pairs at level crossings the nucleons may change from one orbital to another, in case of odd-Z or odd-N nuclei the unpaired nucleon has to 'keep' its level at deformation and thus the energetic most favourable fission path may be forbidden, leading to an increase of the fission barrier, often denoted as 'specialzation' energy. The influence on the fission half-life depends on the change of the energies of the regarded single particle levels at deformation, in other words, on the nuclear structure. Quantitatively it is usually expressed by a hindrance factor HF, defined as HF = T_{sf} / T_{sf}(unh). T_{sf} denotes the partial fission half-life, simply expressed as $T_{sf} = T_{1/2}/b_{sf}$, with $T_{1/2}$ being the half-life and b_{sf} the fission branching. T_{sf}(unh) is the 'unhindered' fission half-life, defined as the geometrical mean of the fission half-lives of the neighbouring even-even nuclei, e.g., in the case of odd-N nuclei $T_{sf}(Z,N)\,(unh) = (T_{sf}(Z,N\text{-}1) \times T_{sf}(Z,N\text{+}1))^{1/2}$ [4].

In fig. 1 hindrance factors are plotted for those odd-mass nuclei for which spin and parity of the fissioning state are assigned beyond reasonable doubt, and the fission branching as well as the fission half-lives of the neighbouring even-even nuclei have been determined experimentally.

Evidently there is no correlation between spin / parity and the hindrance factor. Also hindrance factors for fission from the same Nilsson level are quite different in different nuclei. Eye-catching in even-Z, odd-N nuclei, however, are the higher hindrance factors for the lower-Z nuclei for Nilsson levels with spin-up (↑) projections and the lower hindrance factors for the lower-Z nuclei for Nilsson levels with spin-down (↓) projections. With respect of the low number of cases it is, however, presently too speculative to ascribe it to a nuclear structure effect, it still might be accidential.

In fig. 2 the hindrance factors are plotted versus the fissility parameter Z^2/A of the fissioning nuclei. The black squares denote the nuclei regarded in fig. 1, the coloured ones the nuclei for which spin and parity of the fissioning state is not known or uncertain and /or fission half-lives of at least one even-even neighbour has been taken from theory [5,6]. The magenta squares finally show as a subgroup the values of sf-activities being end products of α-decay chains observed in hot fusion reactions ^{48}Ca + actinide targets and ascribed to the decay of superheavy nuclei with Z > 112 (see e.g. [7]).

Despite the strong straggling of the data a trend towards lower hindrance factors at increasing Z^2/A is indicated, suggesting a lower influence of the odd nucleon on the fission life-times in the region of superheavy nuclei than for the actinides.

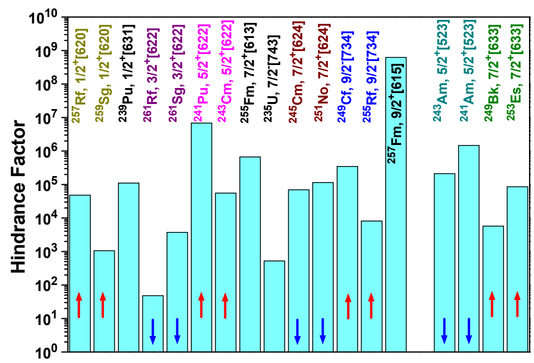

Fig. 1: Experimental sf hindrance factors of odd-mass nuclei

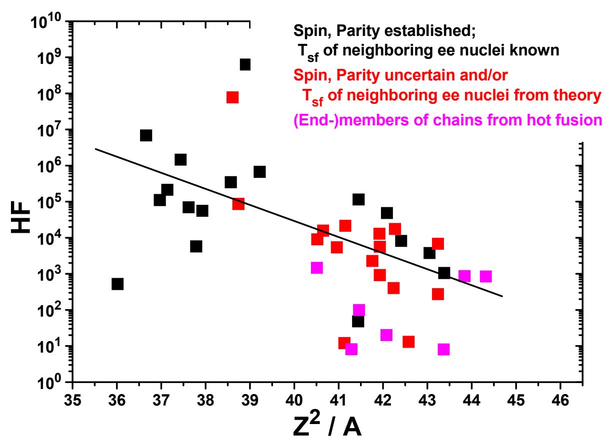

Fig. 2: sf hindrance factors of odd-mass nuclei plotted versus the fissility parameter Z^2/A

References

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