# From the discovery of fission to the synthesis and decay of superheavy nuclei

The synthesis of new element has recently reached an important milestone with the approval and naming by the IUPAC/IUPAP of elements 113, 115, 117 and 118, which eventually fills the 7th period of the Mendeleev table. This achievement has been widely reported in large audience media. However, neither from the chemist nor nuclear physicist point of view is this result an accomplishment in itself. The nuclear landscape at the upper end of the periodic table is not yet delineated, and the position and nature of a predicted island of stability is still not yet know. To give a flavour of the experimental difficulty, only four units of element 118 have been produced so far, despite decades of worldwide efforts. This low cross-section production is related to the large Coulomb repulsion in heavy ions collisions, but also and primarily to the extreme fragility of these objects: the nuclei beyond rutherfordium ($Z = 104$) are solely stabilized by quantum mechanics; a charged liquid drop would fall apart due to Coulomb repulsion. These nuclei are therefore ideal laboratories for exotic nuclear structure studies, especially since different models do not agree on the properties of the heaviest elements. While microscopic-macroscopic models predict $Z = 114$; $N = 184$ as doubly magic numbers, models based on effective forces predict either $Z = 120$ or 126, $N = 172$ or 184. Unfortunately, none of these nuclei can be synthesized using a stable beam, even using a radioactive actinide target. Nuclear physicists have therefore to invent ruses to progress toward the knowledge of the island of stability.

In this lecture, we will make a journey along the heaviest elements from the discovery of fission to the latest synthesis and spectroscopic studies of actinide and transactinide nuclei. Fission will be our starting point since its discovery invalidated some claimed discoveries of elements 93 and 94 using neutron irradiations (actually corresponding to fission, not capture), since it lead to the obvious fact that the Segré chart has an upper frontier, and since it was the starting point of extraordinary discoveries and technical developments. We will present the techniques invented for the synthesis and spectroscopy of elements from neptunium ($Z=93$) to oganesson ($Z=118$) and make a comparison between the techniques and reactions used by the pioneers, and between techniques used nowadays. This parallel concerns the production mechanisms, the identification techniques and the spectroscopic tools. This will be the opportunity to detail the most significant milestones: synthesis of new elements and isotopes, identification using decay properties, evolution from neutron irradiations to fusion-evaporation reactions via transfer and deep-inelastic collisions, decay spectroscopy, prompt gamma and conversion-electron spectroscopy, high-K isomer studies, mass measurement, electromagnetic moment studies, etc. We will also present forthcoming facilities and try to anticipate how progresses will be made in the near and farther future with foreseen facilities and devices. We will try to show that a new view on the radioactivity is always needed to make significant advances in the field. We will also detail the theoretical models on which the predictions are based (this will also be a journey from the early models to the most recent one). Successes but also failures will be outlined. We will in particular show how recent spectroscopic data in the nobelium region pinpoint profound issues, and how theoreticians try to tackle them.

Suggested references:

R.-D. Herzberg and P.T. Greenlees. In-beam and decay spectroscopy of transfermium nuclei. Prog. Part. Nucl. Phys., 61:674, 2008.

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