Available online at www.scholarsresearchlibrary.com

Extended Abstract

Archives of Physics Research, 2018, 09 (3)
(https://www.scholarsresearchlibrary.com/journals/archives-of-physics-research/)

ISSN 0976-0970
CODEN (USA): APRRC7

Exploring the limits: From halo nuclei to super heavy elements - basic research and new medical applications

Gottfried Münzenberg

GSI Helmholtzzentrum für Schwerionenforschung, Germany

E-mail: G.muenzenberg@gsi.de

Exploring the limits of the existence of elementary matter is a primary goal of nuclear physics. New species such as halo nuclei and super heavy elements have been discovered. Experimental methods have been further developed for medical applications including cancer therapy with heavy ion beams and time-of-flight mass spectrometry for medical diagnostics. This work has been largely carried out at the GSI Helmholtzzentrum für Schwerionenforscheung. Light neutron rich nuclei at the limits of nuclear binding develop neutron halos. The nuclear core is surrounded by a halo of dilute neutron matter, heavier species develop a neutron skin. Reaction studies give new insights in nuclear structure. The key instrument for these experiments is the GSI projectile fragment separator (FRS). With the FRS basic research for cancer therapy with heavy ion beams such as the choice of the therapy beam and a special PET diagnostic have been made. Super heavy elements (SHE) at the upper end of the periodic table exist only by shell stabilization. At GSI the new species of deformed shell stabilized SHE has been discovered. The spherical super heavy nuclei predicted for Z=114 are still waiting for discovery though this proton number has already been surpassed with heaviest element observed, oganesson, with 118 protons. To reach this goal the new generation of SHE factories is under way. Drawbacks of the existing experiments are the insufficient sensitivity and the identification by decay characteristics. The new SHE factories will provide more beam intensity for higher sensitivity and direct A, Z identification by isobaric mass measurement with high-resolving multi-reflection time-of-flight mass spectrometers (MRTOF-MS). These spectrometers have a resolving power of 600,000 and are also suitable for the analysis of macro molecules or even cell fragments. Experimental and theoretical studies on phenomenon exhibiting in the unexplored region of the nuclear landscape called exotic nuclei are one of the active current areas in nuclear physics. The study of exotic nuclei has achieved much more attention because of their large ratios (isospin) and exciting properties, such as halo and skin. The exotic nuclei, on the edges of nuclear stability, were first produced in the laboratory only few years back. Later many nuclei in this region have been explored with various experimental methods to interpret this attractive phenomenon better. The measurement of interaction cross sections, nuclear density distribution and nuclear matter radii plays an important role in exploring the properties of exotic nuclei. Among these, the nuclear matter radius is an important basic physical quantity to describe atomic nuclei and understanding not only the proton distribution inside the nucleus but also the exotic phenomena such as the halo and skin observed in exotic nuclei. Such spectrometers are developed at Giessen University. Reason why heavier nuclei are more unstable lies in electrostatic repulsion of protons, which is stronger than the nuclear force at longer distances. Beta decay commonly occur in isotopes of very light elements and is not based on the mass of a nucleus, but alpha decay is only possible for the very heavy elements. Experiments for the identification of exotic nuclei created in transfer reactions are under way. Some of the elements are already used in applications such as smoke detectors (Americium), neutron radiography and neutron interrogation (Curium and Californium), and nuclear weapons (Plutonium). Practical applications may yet be found for elements 113 upward.

Scientifically based searches for elements beyond uranium started after the discovery of the neutron. Neutrons captured by uranium nuclei and subsequent β- decay, similarly as most of the elements were produced in nature, was the successful method applied. However, as a first result, Hahn and Strassmann discovered nuclear fission indicating a limit for the existence of nuclei at an increasing number of protons. Eventually, the nuclear shell model allowed for a more accurate calculation of binding energies, half-lives and decay modes of the heaviest nuclei. Theoreticians predicted a region of increased stability at proton number $Z = 126$, later shifted to 114, and neutron number $N = 184$. These nuclei receive their stability from closed shells for the protons and neutrons. Later, increased stability was also predicted for deformed nuclei at $Z = 108$ and $N = 162$. In this review I will report on experimental work performed on research to produce and identify these super-heavy nuclei (SHN). Intensive heavy ion beams, sophisticated target technology, efficient electromagnetic ion separators, and sensitive detector arrays were the prerequisites for discovery of 12 new elements during the last 40 years. The results are described and compared with theoretical predictions and interpretations. An outlook is given on further improvement of experimental facilities which will be needed for exploration of the extension and structure of the island of SHN, in particular for searching for isotopes with longer half-lives predicted to be located in the south east of the island, for new elements, and last not least, for surprises which, naturally, emerge unexpectedly.

Bottom Note: *This work is partly presented at 4th International Conference on Physics September 17-18, 2018, Berlin, Germany*