ACAD. AURELIU SĂNDULESCU'S CONTRIBUTION TO PHYSICS: FROM MAGIC RADIOACTIVITY TO SUPERHEAVY NUCLEI

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During the seventies of the last century most scientists considered that the basic phenomena connected with the "traditional" low-energy nuclear physics were already discovered and the theoretical work should be concentrated on their better description. Anyway, thirty years ago Prof. Aureliu Săndulescu's intuition contradicted this opinion by predicting a new type of radioactivity. Nowdays it is widely recognized that the theoretical prediction of spontaneous heavy cluster emission in 1977 [1, 2] and in the later reference [3] was the next significant achievement, after the discovery of α, β and γ types of radioactivity in 1986 by Henry Becquerel, awarded the Nobel prize in 1903.

Heavy cluster emission is sometimes called "magic radioactivity" because one of the fragments is the double magic nucleus ^{208}Pb, or close to it. From this point of view this phenomenon is a "relative" of the well-known α-decay where another, much lighter, double magic nucleus ^{4}He is emitted. Thus, heavy cluster emission is actually some kind of "Pb-radioactivity". Indeed, its theoretical prediction was based on the discovery of the so-called cold valleys in the potential energy of those binary partitions containing a partner close to the double magic nucleus ^{208}Pb, similar to the already known α-particle valleys.

The major difficulty in convincing experimentalists to detect heavy particle emission was the very small decay width, due to two factors, namely the much smaller cluster preformation probability and the penetration through a much larger Coulomb barrier in comparison with the α-decay. It was predicted only one event for ^{14}C emission, compared with 10^{10} α-decays. Anyway, this new type of radioactivity was experimentally confirmed in 1984 by H. J. Rose and G. A. Jones, at the Oxford University [4]. During 189 days they detected 65 billions α-decays, together with 11 events of ^{14}C emission from the ^{223}Ra isotope, produced by a natural dezintegration of ^{227}Ac. The experiment was independently confirmed [5] with a close decay rate.

In 1985, the spontaneous emission of a heavier cluster, namely ^{24}Ne from ^{231}Pa, ^{233}U and ^{230}Th, was detected by prof. A. Săndulescu and prof. S. P. Tretyakova in Dubna [6, 7]. The results (one event compared with 500 billions

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α-decays) were very soon confirmed by prof. B. Price and coworkers in Berkeley [8].

In the years after these major developements the experimental techniques improved. Thus, there were detected clusters like oxygen, magnesium or silicon [9]. The largest known half-life in heavy cluster radioactivity is 10^{29} seconds for the neon emission, as can be seen from Fig. 1.

Heavy cluster emission is an intermediate decay mode between α-decay and fission. It is mentioned, together with the reference [3] in *The New Encyclopaedia Britannica*, 15th edition, vol. 14, p. 371, (Encyclopaedia Britannica, Inc. 1998) as the fourth kind of radioactivity, together with α, β and γ decays. It also was introduced in the Physics and Astronomy Classification Scheme (PACS): **23.70.+j Heavy-particle decay**.

The investigation of cold valleys for various binary combinations by prof. A. Săndulescu led in the same period to a new important discovery, connected

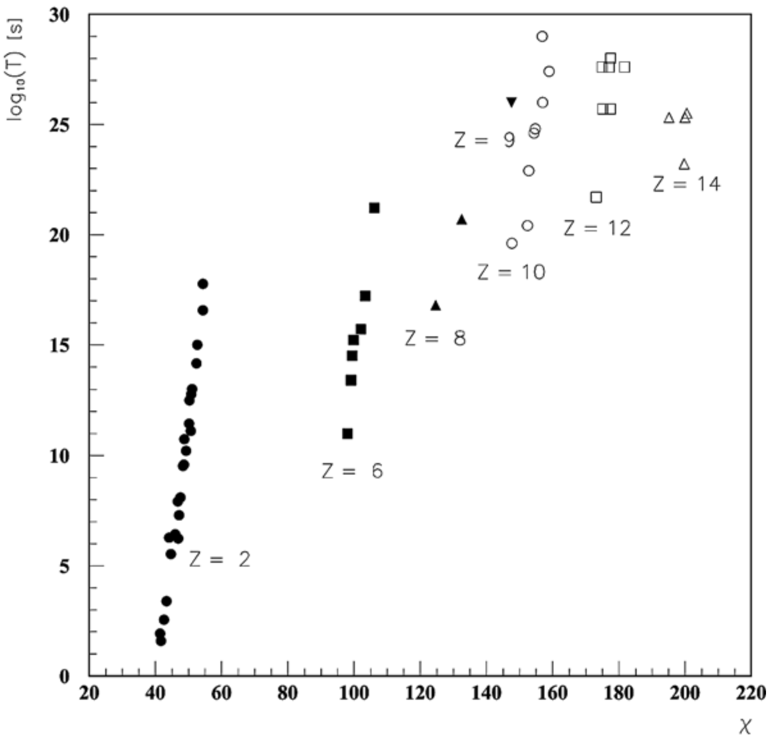

Fig. 1 – Logarithm of the half-life (in seconds) as a function of the Sommerfeld parameter (proportional to the product between fragment charges and inverse proportional to the square root of the emission energy). Different symbols denote the emitted particle, *i.e.*, carbon ($Z = 6$), oxygen ($Z = 8$), fluorine ($Z = 9$), neon ($Z = 10$), magnesium ($Z = 12$) and silicon ($Z = 14$). The α-decay half-lives ($Z = 2$) corresponding to heavy cluster emitters are also shown.

with one of the most active fields in today's nuclear physics, namely the production of new superheavy elements. In the middle of the seventies A. Săndulescu and W. Greiner pointed out the necessity to bombard double magic nuclei with suitable projectiles. Thus, a real prediction for $Z = 104$, 106 elements was performed [10]. The main idea was to overcome the quasifission phenomenon, hindering the possibility to obtain superheavy elements, by using the cold fragmentation valleys in the potential energy surface between different combinations giving the same compound nucleus. Later on, in the reference [11] it was shown that the most favorable combinations with $Z \geq 104$ are connected with the so-called Pb potential valley, *i.e.*, the same valley of the heavy cluster emission.

An example for the cold fission of ^{252}No is shown in Fig. 2. In this way it was possible to synthetize in Darmstadt nuclei with $Z \leq 112$ [12].

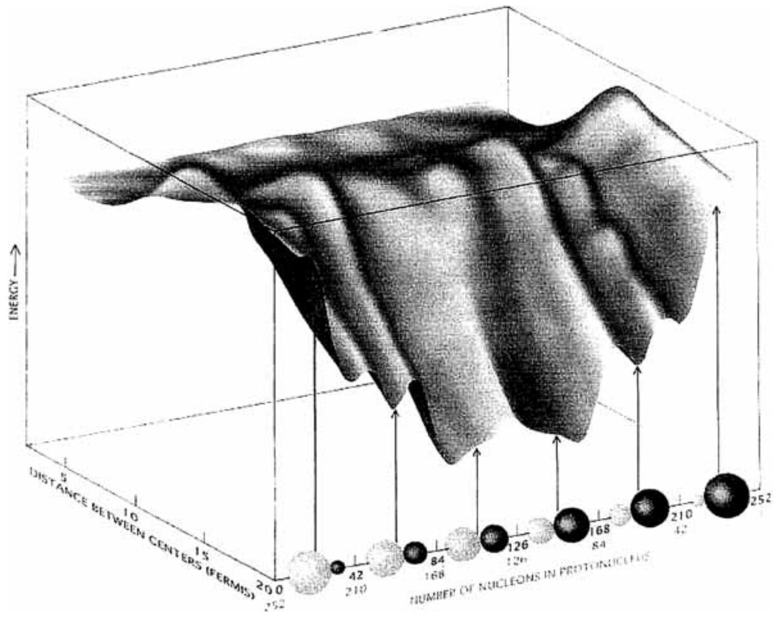

Fig. 2 – Energy surface of the nucleus ^{252}No *versus* the distance between centers and mass numbers of the emitted fragments. The valleys indicate the most probable cold paths, corresponding to ^{158}Gd+^{94}Sr, ^{192}Os+^{60}Fe, and ^{214}Rn+^{38}S.

Evidently the fragmentation valley corresponding to the double magic nucleus ^{48}Ca can be used in order to reach the region beyond $Z \geq 114$. Due to its double magicity and a large number of neutrons, it became possible to set up a new generation of experiments in order to search for new superheavy elements by using ^{48}Ca [12, 13, 14] as a projectile on various transuranium targets. In this way this method is the only possibility to reach the border of the hypotetical "island of stability", predicted by many theoretical works [12]. Nowdays it is worldwide recognized that the production of many superheavy elements with $Z \leq 118$ in Dubna during last three decades was based on this proposal [12, 15]. Recently, based on the same idea of cold vallyes, Acad. A. Săndulescu proposed the use of new projectiles like ^{54}Cr and ^{56}Fe, in order to go beyond $Z = 118$ [16].

These ideas together with the prediction of the "magic radioactivity" are, beyond any doubt, among the most important achievements of the Romanian physics and we owe them to Acad. Aureliu Săndulescu, who celebrates this year his 75th anniversary.

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