The making of moscovium

Yuri Oganessian relates the story of the formation and decay of a doubly odd moscovium nucleus.

Element 115 was the first superheavy element with an odd atomic number (Z) that we synthesized in nuclear reactions using a beam of accelerated ^{48}Ca ions. These experiments were carried out in 2003, on the heels of the first results obtained for even elements 114 and 116. We had no doubts that their odd neighbour could also be produced in a similar manner; its decay properties however would be very different.

The target isotope ^{243}Am ($Z = 95$) was bombarded with ions of ^{48}Ca ($Z = 20$) in the hope that a rare process — the fusion of these nuclei — would occur. A ^{291}115 nucleus did indeed form. During the process this nucleus was heated (to around 4×10^{11} K), and cooled down through the very fast emission of three neutrons, and gamma rays, to form the isotope ^{288}115. The thickness of the americium target was chosen so that once made, the ^{288}115 nucleus, with the recoil energy obtained in collision, can escape out of the target. Its time of flight on the 4-metre path from the target to the detector through the separator is only about one microsecond. The separator was configured and tuned to allow the superheavy nuclei formed to pass through, yet sweep away all the lighter by-products of the reaction from the main trajectory. The atoms of interest reach the detector assembly, enabling the detection of nuclei formed by determination of their decay patterns.

Two types of radioactive decay compete in superheavy elements: alpha-decay and spontaneous fission. The former, discovered by Henri Becquerel in 1898, is the spontaneous emission of an alpha particle (^{4}He) by a heavy nucleus; it is typical of many nuclei heavier than lead. The latter, in which a nucleus splits into two fragments, was discovered by Georgy Flerov and Konstantin Petrjak in 1940. It is observed only for actinides and transactinides, and its probability rises rapidly with increasing atomic number. According to the classic (macroscopic) nuclear theory, spontaneous fission sets the limit of elements that can exist at $Z = 100$ (fermium).

Credit: Loop Images Ltd / Alamy Stock Photo

In 1969 a new (microscopic) theory was devised that takes into account the structure of nuclear matter, giving different predictions: stability is expected to increase again in the domain of very heavy, neutron-rich nuclei (with mass numbers around 280–300). Near ‘magic’ numbers of protons and neutrons, $Z = 114$ and $N = 184$, a vast area of relatively stable elements appears in the periodic table that is dubbed the island of stability; element 115 is one of these. Additionally, the internal structure of the ^{288}115 nucleus — with odd numbers of protons and neutrons ($Z = 115$, $N = 173$) — largely prevents spontaneous fission, so it is likely that the nucleus will undergo alpha decay.

Emission of an alpha particle forms an odd–odd nucleus of the element 113 that, for the same reasons, will also undergo alpha decay. This decay pattern is reproduced with the element 111, then 109, and so on. At each step of this odd–odd stairway we decrease the atomic number of the nucleus by two, and we move away by two neutrons from the magic number $N = 184$. As a result, the nucleus becomes more stable to alpha decay, but more prone to spontaneous fission and eventually the chain will be terminated by spontaneous fission. At what point will this happen? Only experiments will tell.

In our 2003 experiments, detectors allowed us to document the entire radioactive family of the nuclei formed, and to determine the energy and time of emission of each alpha particle emitted as well as the energy of the fragments of spontaneous fission. The decay chain of the ^{288}115 isotope obtained is pictured. After five consecutive alpha transitions within the first 20 seconds, there was a long pause, which brought us a lot of trouble. Spontaneous fission of the last nucleus in the chain — the isotope ^{268}Db — was registered only the next day, after 30–40 hours. We think that the isotope ^{268}Db ($Z = 105$, $N = 163$) decayed through electron capture to give an even–even ^{268}Rf nucleus ($Z = 104$, $N = 164$), which then quickly divided into two fragments. In our first experiments we detected a total of three such events. Since then, a similar picture of the decay of element 115 has been observed over a hundred times in Dubna (Russia), Darmstadt (Germany) and Berkeley (United States).

The name we proposed for element 115, located in the periodic table at the bottom of group 15 under bismuth, was adopted: ‘moscovium’, in honour of the ancient Russian land of Moscovia, the Moscow region where the people who first produced it and observed its spontaneous transmutation into other elements lived and worked. ❒

Yuri Oganessian
Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, Dubna, Moscow region, Russia.
e-mail: oganessian@jinr.ru

Published online: 14 December 2018
https://doi.org/10.1038/s41557-018-0185-6

Cn Nh Fl Mc Lv Ts Og 119 120 121 122 123 124 125 126 127 128 129 130 131 132