Synthesis, chemical identification and study of properties of superheavy elements

S.N. Dmitriev

Flerov Laboratory of Nuclear Reactions, Joint Institute for Nuclear Research, 141980 Dubna, Russia

Abstract – Results of experiments designed to synthesize, perform chemical identification and study the properties of superheavy elements are presented. For the production of superheavy nuclides a fusion reaction of heavy actinide nuclei with ^{48}Ca-projectiles have been used. A program of the future SHE experiments (new reactions, mass-analysis, search in nature) is discussed.

Keywords – superheavy elements, dubnium, 112 and 114 elements, gas chromatography, adsorption, mass-separation

The synthesis of new elements carried out within the past years in the fusion reactions between accelerated ^{48}Ca ions and nuclear targets ^{238}U, ^{237}Np, ^{242,244}Pu, ^{243}Am, ^{245,248}Cm and ^{249}Cf was the first experimental evidence of the existence of "islands of stability" of superheavy elements [1]. The half-lives of the new nuclides vary from 0.5 ms to 30 h depending on the proton and neutron numbers in the synthesized nuclei. The synthesis of all the new nuclides was performed using at the U400 accelerator complex with the Dubna gasfilled recoil separator (DGFRS) of the FLNR, JINR. Relatively long life times of the new nuclides allowed the conduction of the first experiments devoted to their chemical identification and study of their properties. The identification of the decay chain of element 115 synthesized in the reaction ^{243}Am (^{48}Ca, 3n) was performed by the finite decay product, i.e., the element 105 isotope (^{268}Db, T1/2 = 29 час) which is a homologue of Ta and Nb [2,3]. The chemical identification of elements 112 and 114 produced in the reactions ^{242}Pu(^{48}Ca,3n)^{287}114 (α) → ^{283}112 and ^{244}Pu(^{48}Ca,4n)^{288}114 (α) → ^{284}112 was of special interest since due to the influence of relativistic effects one could expect a substantial difference in their chemical properties as compared with those of more light homologues (Hg and Pb, respectively). Such experiments, in which the volatility and adsorption on Au surface at temperatures from + 25^{0}C to – 180^{0}C were studied, were carried out at the FLNR, JINR in 2006-2007 [4-6]. It was shown that element 112 is close in its properties to Hg (instead of Rn). Element 114 differs greatly from Pb (volatile, adsorption on Au surface was observed at temperatures about –80^{0}C). This observation exposes for the first time the predominant primary relativistic effect leading to the stronger binding of the 7s and $7p_{1/2}$ valence electrons of element 114. On the whole, the data from chemical experiments are in full agreement with the results of DGFR experiments and are the independent evidence of the synthesis of elements 112, 114 and 116 in the reactions ^{48}Ca+^{242,244}Pu and the synthesis of elements 113 and 115 in the reaction ^{48}Ca+^{243}Am.

Experiments on the chemical identification of elements 112, 114 and 115 were carried out in collaboration with the PSI (Switzerland) and LLNL (USA).

The programme of further research includes:

- continuation of experiments on the determination of chemical properties of isotopes of elements 114 and 112 produced in the reaction of ^{244}Pu and ^{48}Ca;
- carrying out experiments on the determination of the masses of isotopes of elements 114 and 112 produced in the reaction of ^{244}Pu and ^{48}Ca using a newly created at the FLNR Mass Analyzer of Super Heavy Atoms (MASHA);
- searching for SHE in nature (neutron detector allowing high efficiency of detecting multiple neutron emission from spontaneous fission of superheavy nuclei, MASHA, Os and Xe samples).

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