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Observation of the decay of $^{292}116$

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We present the observation of the first decay event of the new nuclide $^{292}116$ in the running experiment on the synthesis of $Z=116$ nuclei in the reaction $^{248}\text{Cm}+{}^{48}\text{Ca}$. The experiment is in progress at FLNR, JINR, Dubna.

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A beam of $^{48}\text{Ca}^{+5}$ ions was delivered by the U400 cyclotron at FLNR, JINR, operated with the ECR-4M ion source. The average beam intensity at the target was 0.7 pμA at the consumption rate of the ^{48}Ca material of ~ 0.3 mg h^{-1}. The 32-cm^2 rotating target consisted of the enriched isotope ^{248}Cm (96.3%) in the form of CmO_2 deposited onto 1.5-μm Ti foils to a thickness of ~ 0.32 mg cm^{-2}.

The evaporation residues (EVRs) recoiling from the target were separated in flight from the ^{48}Ca beam ions, scattered particles, and transfer-reaction products by the Dubna Gas-filled Recoil Separator [1]. The transmission efficiency of the separator for $Z=116$ nuclei was estimated to be about 35%.

A detection array was situated in the separator's focal plane. This consisted of a time-of-flight system (TOF) followed by a 4×12-cm^2 semiconductor detector array with 12 vertical position-sensitive strips, in which the recoils were implanted. This detector, in turn, was surrounded by eight 4×4-cm^2 side detectors without position sensitivity, forming a box of detectors open from the front side. The detection efficiency for α decays of implanted nuclei was 87% of 4π. The detection system was tested by registering the recoil nuclei and α and SF decays of the known isotopes of No produced in the reactions $^{204,206-208}\text{Pb}(^{48}\text{Ca},xn)$. According to the measured position resolutions, more than 95% of genetically linked signals in the focal-plane detector appear in a position window of $\Delta y=1.4$ mm.

The energy resolution for α particles absorbed in the focal-plane detector was about 55 keV. For α's escaping the focal-plane detector and registered by side detectors, the energy resolution of the summed signals was ~ 190 keV.

Fission fragments from ^{252}No implants produced in the $^{206}\text{Pb}+{}^{48}\text{Ca}$ reaction were used for a fission-energy calibration. The measured fragment energies were not corrected for the pulse-height defect of the detectors. The energies of fragments registered by the side detectors were also not corrected for energy loss in the detectors' entrance windows, dead layers, and the pentane gas filling the detection system. The mean sum energy loss of both fission fragments for ^{252}No was about 20 MeV; for fission fragments escaping the focal-plane detector at a small angle this value could be higher.

We chose the bombarding energy for ^{48}Ca ions of 240 MeV in the middle of the target. With the ~ 1.5-MeV beam energy resolution, variation of the beam energy during irradiation (± 0.9 MeV), and energy losses in the target (~ 2.8 MeV), we expected the resulting compound nucleus $^{296}116$ to have an excitation energy between 30.4 MeV and 35.8 MeV. Thus, the compound nuclei should deexcite most probably by the evaporation of three or four neutrons and γ rays which would result in the production of isotopes of element 116 with neutron numbers $N=176$ and 177. Alpha decays of the nuclides $^{292,293}116$ lead to the known isotopes of element 114 which were produced in our recent experiments via the reactions $^{244}\text{Pu}(^{48}\text{Ca},\ 3-4n)^{288,289}114$ [2,3]. Their chains of sequential decays should be observed, following α-particle emission from the parent nuclei with $Z=116$.

To improve background conditions for detecting long-time decay sequences, a special measurement mode was employed [1]. The beam was switched off after a recoil signal was detected with parameters of implantation energy and TOF expected for $Z=116$ evaporation residues, followed by an α-like signal with an energy of 10.25 MeV $\leqslant E_\alpha \leqslant 11.5$ MeV, in the same strip, within a position window $\Delta y=2$ mm and time interval of 1 s. The duration of the pause was determined from the observed pattern of out-of-beam α decays and varied from 5 to 60 minutes. Thus, all the expected sequential decays of the daughter nuclides with $Z\leqslant 114$ could be observed in the absence of beam-associated background. With the full beam intensity on target, the average counting rate of such ''EVR$\rightarrow\alpha$'' events was less than one per 3 h. The total counting rate for α particles with $E_\alpha > 8$ MeV by the whole detector array during beam-off pauses was about 2 h^{-1}.

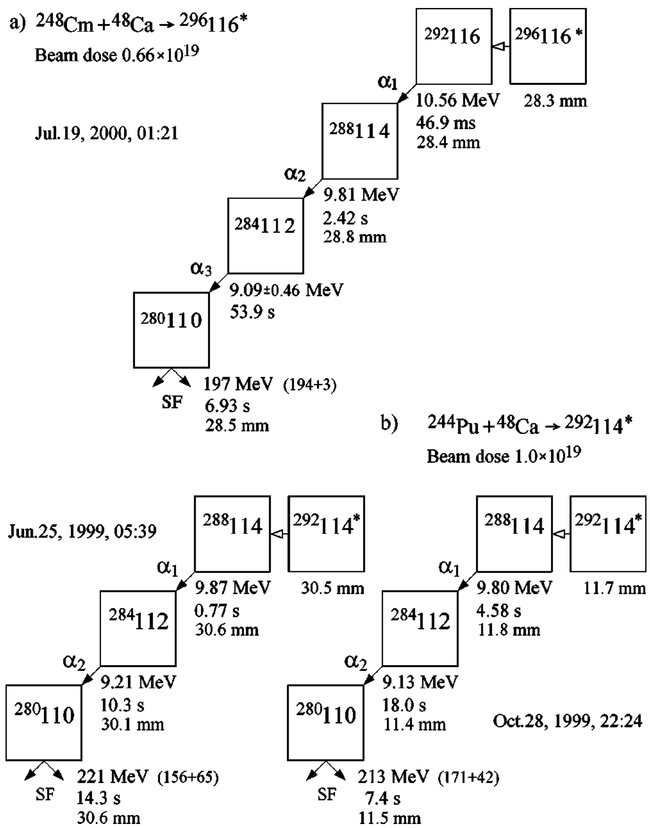

FIG. 1. (a) Time sequence in the observed decay chain. (b) Two decay sequences of ^{288}114 observed in the ^{244}Pu+^{48}Ca reaction. Vertical positions of the observed events are given with respect to the top of the strip. Values in parentheses show fission energies measured by the focal-plane and side detectors, respectively.

On the 35th day of irradiation, after an accumulated beam dose of 6.6×10^{18} ions, the first event sequence was observed that can be assigned to the implantation and decay of the isotope of element 116 with mass number 292 [see Fig. 1(a)]. The implantation of a heavy recoil in strip 4 of the focal-plane detector was followed in 46.9 ms by an α particle with $E_\alpha=10.56$ MeV. This sequence switched the ion beam off, and further decays were detected under lower-background conditions. A second α particle with $E_\alpha=9.81$ MeV was observed 2.42 s later. Then, after 53.87 s a third α decay with the energy of 8.63 MeV was registered by a side detector only. The energy deposited by this α particle in the focal-plane detector was not registered because it was lower than the detection threshold of 0.92 MeV. However, the probability that the third α particle appeared in the chain ($\Delta t\sim1$ min) as a random event can be estimated as only $\sim1\%$, so we assign it to the decay of the same implanted nucleus. Thus, its total energy is determined with a larger uncertainty to be $E_\alpha=9.09\pm0.46$ MeV.

Finally, 6.93 s after the last α decay, two coincident fission fragments with a total energy of 197 MeV were registered by both the focal-plane and the side detectors. The low energy of the fission fragment measured by the side detector for this event implies a large amount of energy was lost by this fragment in the dead layers of the detectors.

Positions of the four events with signals registered in the focal-plane detectors (EVR, α_1, α_2, and SF) were measured to be within a window of 0.5 mm, and all events appeared within a time interval of 63.26 s, which points to a strong probability of correlation between them. The probability of the observed event chain being totally of random origin is negligible ($\ll10^{-6}$) [4–6].

All the decays following the first 10.56-MeV α particle agree well with the decay chains of ^{288}114, previously observed in the ^{244}Pu+^{48}Ca reaction [see Fig. 1(b)]. Thus, it is reasonable to assign the observed decay to the nuclide ^{292}116, produced via evaporation of four neutrons in the complete-fusion reaction ^{248}Cm+^{48}Ca. All the decay chain members follow the Geiger-Nuttall Q_α vs T_α relationship for even-even nuclei. Substituting the values ($E_\alpha=9.83\pm0.05$ MeV and $T_\alpha=1.8^{+2.1}_{-0.6}$ s) measured in the ^{244}Pu+^{48}Ca reaction (mother nuclide) and ^{248}Cm+^{48}Ca (daughter nuclide) into the formula by Viola and Seaborg with parameters fitted to the all known even-even nuclides with $Z>82$ and $N>126$ [7], results in the atomic number $Z=114.3^{+1.2}_{-0.8}$. The decay energy $Q_\alpha=10.71$ MeV of the newly observed nuclide and a half-life estimated from one event as $T_\alpha=33^{+155}_{-15}$ ms agree with theoretical predictions of the stability island in the domain of superheavy elements around $Z=114$ and $N=184$. Further experiments are in progress.

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