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Short note

The new isotope ^{217}U

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Abstract. The new neutron deficient isotope ^{217}U was produced in the bombardment of the ^{182}W target with ^{40}Ar ions and identified using a recoil-α-α correlation method. The α-decay energy and the half-life of ^{217}U were determined to be 8005 ± 20 keV and $15.6^{+21.3}_{-5.7}$ ms, respectively.

PACS. 23.60.+e α decay – 25.70.-z Low and intermediate energy heavy-ion reactions – 27.80.+w 190≤A≤219

1 Experiment

In the past we performed a number of experiments aimed at the synthesis of neutron deficient uranium isotopes [1–3]. The last one studied was ^{218}U with a "magic" number of neutrons $N = 126$. It was of special interest to study the next isotope—^{217}U, located just beyond the $N = 126$ shell closure, in order to compare a trend in the half-life behaviour at crossing the neutron shell $N = 126$ with that of the other even-Z isotopes of Th and Ra and with theoretical predictions.

The experiments were performed with a ^{40}Ar beam from the U-400 cyclotron of the Flerov Laboratory of Nuclear Reactions, JINR, Dubna. The beam energy was 193 ± 2 MeV, that corresponded to the calculated maximum of the fusion reaction with a following evaporation of 5 neutrons. The beam energy was controlled by measuring the energy of the ions scattered at an angle of 30° from a thin gold foil (200 μg/cm^2) and by measuring the time of flight between two pick-up detectors. An isotopically enriched (92%) ^{182}W target (320 ± 30) μg/cm^2 in thickness evaporated onto a 1.5 μm titanium backing foil was mounted on a standing rigid frame. Due to this fact the beam intensity on the target was limited and amounted to about 2×10^{11} particles per second. The evaporation residues (ERs) recoiling from the target were separated in flight from the projectiles and other unwanted reaction products by the VASSILISSA recoil separator [4]. The optimal field settings and transmission efficiency of the ERs for the reaction ^{40}Ar + ^{182}W were chosen according to the calculated mean charge states, angular distributions and energies of ERs [5] and were checked in preparatory experiments. For the registration of the ERs and their radioactive decays a system of time-of-flight (TOF) detectors and a silicon position-sensitive strip-detector array were installed in the focal plane of the separator. After the registration by the TOF detectors the recoiled ions were implanted into the multi-strip silicon focal plane detector, which had 16 strips and an active area of 60 × 60 mm^2. Each strip was position sensitive in the longitudinal direction. The position resolution along each strip was measured from test reactions. A value of 0.6 mm (FWHM) was obtained for sequential α-α decays, and 1.0 mm for ER-α [6]. The energy resolution for α particles was 20 keV within an energy range from 5 to 9 MeV. The accuracy of the time registration for recording the events was about 1 μs. In order to increase the detection efficiency for α-particles, the focal plane detector was surrounded by detectors of the same size and number of the strips as the stop detector. For the detection by the side detectors of α particles escaping from the focal plane detector, the energy resolution was ≈ 150 keV. The efficiency of the silicon array for detecting α particles with full energy was 85 % of 4π. The signals from the TOF detectors were used both for measuring the velocity of the ERs and for distinguishing radioactive decays of previously implanted nuclei. Alpha energy calibrations were performed using the α peaks from nuclides produced in the test reactions.

2 Results

The isotope identification was performed using the method of ER-α-α delayed coincidence analysis. The decay events

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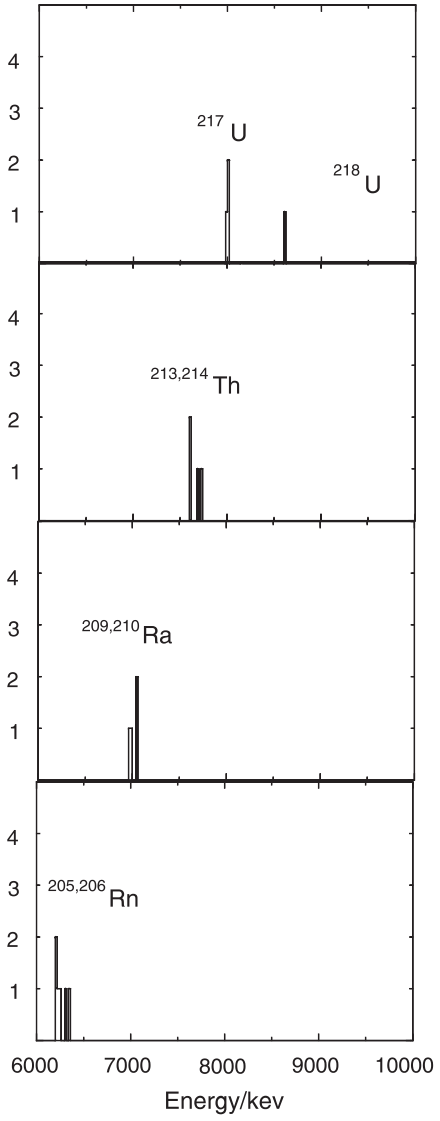

Fig. 1. Delayed α-α coincidence spectra showing four generations of α-decays beginning from ^{217,218}U.

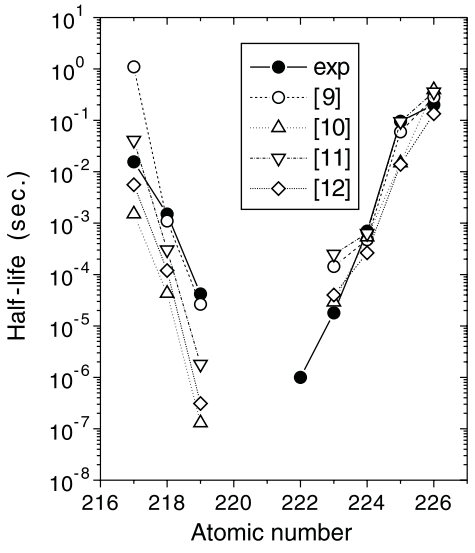

Fig. 2. Comparison of half-lives of the U isotopes observed experimentally (filled circles) with the calculated values according to refs. [9–12] (open symbols).

Table 1. α-α correlated events assigned to ^{217,218}U.

	E_α (keV)	Δt	Δx (mm)
^{218}U	8603	0.328 ms	0.9
^{214}Th	–	–	–
^{210}Ra	7059	32.2 s	0.18
^{206}Rn	6255	252 s	0.6
^{217}U	8018	1.596 ms	0.9
^{213}Th	7607	34 ms	0.36
^{209}Ra	–	–	–
^{205}Rn	6267	25.7 s	0.12
^{217}U	8002	60.5 ms	0.36
^{213}Th	7682	423 ms	0.9
^{209}Ra	7099	953 ms	0.72
^{205}Rn	6204	449.7 s	1.2
^{217}U	7996	5.5 ms	0.3
^{213}Th	7701	215 ms	0.72
^{209}Ra	7025	12.5 s	0.3
^{205}Rn	6210	551 s	0.6

associated with ^{217}U were selected by searching for position and time correlated α-decay chains having from two to four members. The energy of the first event in the chain was allowed to vary freely, under the condition that it must be followed by subsequent events with energies and time intervals corresponding to the daughter isotopes ^{213}Th, ^{209}Ra and ^{205}Rn. The energy windows were $\pm$ 100 keV from the tabulated values for the known isotopes [7], the time windows were equal to five half-lives of the known daughter isotopes. The spectrum of the correlated events extracted using these search criteria is shown in fig. 1. The opening of the energy windows up to $\pm$ 250 keV did not change the correlation picture. The additional correlation chains belonging to the decays ^{216}Th $\rightarrow$ ^{212}Ra $\rightarrow$ ^{208}Rn and ^{214,215}Pa $\rightarrow$ ^{210,211}Ac were found, but they could be easily distinguished from the decays of ^{217}U due to the presence of the decay of the daughter nucleus ^{213}Th (E_α = 7689 keV).

One primary (mother) event presented in the upper panel of fig. 1 with a decay energy of 8603 keV and the life-time (time difference between the corresponding ER and α-decay events) of 0.33 ms was attributed to the previously studied isotope ^{218}U [1], which could be synthesized in the reaction ^{40}Ar + ^{182}W $\rightarrow$ ^{218}U + 4n. The decay properties of its descendant isotopes are very close to those of the descendants of the ^{217}U decay. A group of three events (upper panel of fig. 1) with a mean energy of 8005 $\pm$ 20 keV was attributed to the decay of the new isotope ^{217}U. These events are listed in the table 1. The half-life of the new isotope was calculated from the time intervals of subsequent ER-α events and was determined to be $15.6^{+21.3}_{-5.7}$ ms. Using the calculated separation efficiency of VASSILISSA (25%), the production cross-section for ^{217}U

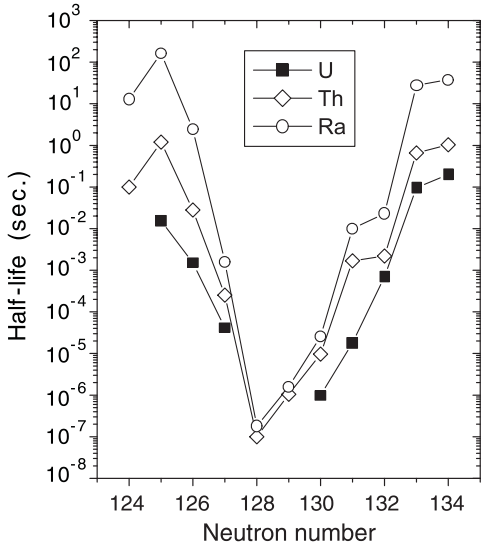

Fig. 3. Comparison of half-lives of the U isotopes (filled circles) with values for Th and Ra isotopes (open symbols).

at the ^{40}Ar beam energy of 193 MeV was determined to be σ_{5n}=$1^{+0.9}_{-0.6}$ nb. The error bars represent statistical errors only and were calculated according to the method described in [8] for the case of low statistics.

To reproduce the measured half-life value the calculations were carried out using semi-empirical formulae [9–12]. In fig. 2 the calculated and experimental half-life values for U isotopes are compared. One can see that for the neutron numbers $N \geq 130$ the calculations are in rather good agreement with experimental results, but for $N \leq 127$ there may be a difference of a few orders of magnitude. A comparison of U half-lives with the half-life values for other even-Z Th and Ra isotopes is presented in fig. 3. A common trend in the behaviour of the half-lives of even-Z U, Th and Ra elements is obvious with a decrease in the neutron number from $N = 134$ to $N = 125$ and at the crossing of the $N = 126$ closed shell. To continue this comparison it is very important to study the decay properties of ^{216}U ($N = 124$) in order to see if the half-life of this isotope follows the trend in the behaviour of Th and Ra isotopes and decreases its value. The isotope ^{216}U could be synthesized in the reactions ^{40}Ar + ^{180}W $\rightarrow$ ^{216}U + 4n or ^{40}Ar + ^{182}W $\rightarrow$ ^{216}U + 6n. But in the latter case the cross-section could be small enough.

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