New isotope candidates, ^{215}U and ^{216}U

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Theory[1] predicts that nuclei with $N = 126$ exist up to Fm($Z = 100$) because of the appearance of the fission barrier originating from the ground-state shell correction. The heaviest $N = 126$ nuclei reported so far is ^{218}U($Z = 92$). In this paper, we attempt to produce heavier nuclei such as ^{220}Pu. In our experiment, we observed a new isotope, ^{216}U, which is the daughter nucleus of ^{220}Pu.

We performed an experiment at the RIKEN Linear Accelerator (RILAC) facility. We used ^{82}Kr beams of 372 and 387 MeV to bombard a rotating $BaCO_3$ target foil having a thickness of approximately 400 μg/cm^2. To determine the efficient reaction for the production of ^{216}U, we studied the reaction ^{82}Kr + ^{136,137,138}Ba leading to the same nucleus ^{216}U with different neutron evaporation channels. Each $^{136,137,138}BaCO_3$ target was prepared by sputtering on 0.8–2.3-μm-thick aluminum foils, and they were also covered with 40 μg/cm^2 of aluminum by sputtering. Several 0.8-μm- and 1.1-μm-thick aluminum foils were prepared as the degraders. The beam energies at the center of the target were changed from 344 to 374 MeV by combining backings and degraders to obtain the excitation function. Evaporation residues (ERs) were separated from the beam particles and other reaction products using a gas-filled recoil ion separator (GARIS), and they were implanted into a position-sensitive strip detector (PSD; 58 × 58 mm^2) at the focal plane. Two timing detectors were set in front of the PSD to determine the time-of-flight (TOF) of the ERs. Time information was also used to distinguish between the α-decay events in the PSD and the recoil implantations. A Ge-detector was placed 6 mm behind the PSD for the α-γ coincidence measurement. In this experiment, 1.7 × 10^{17} and 2.7 × 10^{17} beam doses were accumulated at 372 MeV and 387 MeV, respectively.

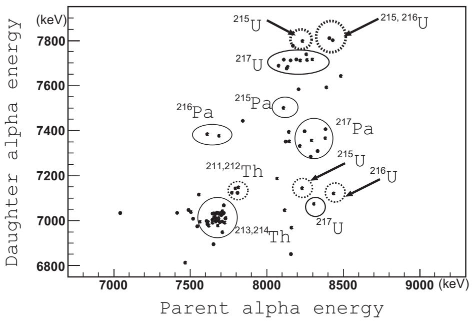

Fig. 1. α-α correlation spectrum. The time difference between the implanted ERs and the parent α-decay, and between the parent and the daughter α-decays were within 150 ms and 2.2 s, respectively. The horizontal and vertical position windows in the PSD were within the same strip (~3.6 mm width) and ±1.5 mm, respectively.

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Isotope identification was performed by using an α-decay chain with the help of known α-decay properties (energies and half-lives) of the descendants and the position correlations between the implanted ERs in the PSD and the subsequent α-decays. Figure 1 shows an α-α correlation spectrum obtained in this experiment. In Fig. 1, the candidates of the new isotopes, ^{215}U and ^{216}U, were observed. These α-decay properties and the obtained cross sections are summarized in Table 1. The decay energies and half-lives of these descendants agree well with those of the references. In the future, an additional irradiation experiment will be performed to confirm the production of ^{215}U and ^{216}U.

Table 1. α-α correlated events of ^{215}U and ^{216}U. The time and position difference between the implanted ERs and the α-decay are ΔT and ΔX, respectively. E_{beam} represents the ^{82}Kr beam energy at the center of the target.

	E_α (keV)	ΔT	ΔX (mm)	Reaction (E_{beam}) Cross section
^{216}U	8408	6.98 ms	0.15	^{137}Ba+^{82}Kr (365)
^{212}Th	7811	43.4 ms	0.12	→ ^{216}U + 3n
^{208}Ra	7144	2.23 s	1.12	$0.19^{+0.44}_{-0.16}$ nb
^{204}Rn	6424	34.7 s	0.14	
^{215}U	8436	5.82 ms	1.02	^{136}Ba + ^{82}Kr (374)
^{211}Th	7807	29.1 ms	0.72	→ ^{215}U + 3n
^{207}Ra	7124	773 ms	0.36	$0.34^{+0.49}_{-0.22}$ nb
^{203}Rn	6474	45.6 s	2.71	
^{215}U	8230	635 μs	0.35	
^{211}Th	7799	59.9 ms	0.99	
^{207}Ra	7145	1.06 s	0.39	

	E_α (keV) ref.	$T_{1/2}$ ref.	α-decay branch
^{212}Th	7802±10	30^{+20}_{-10} ms	99.7%
^{208}Ra	7133±5	1.3±0.2 s	95%
^{204}Rn	6418.9±0.4	74.4±1.8 s	72.4%
^{211}Th	7792±14	37^{+28}_{-11} ms	~100%
^{207}Ra	7131±4	1.2±0.1 s	≤100%
^{203}Rn	6.499±2	44±2 s	66%

References

1) H. Koura and T. Tachibana: Butsuri (in Japanese), 60, 717 (2005).