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Alpha-decay study of ^{218}U; a search for the sub-shell closure at Z = 92

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Abstract. Neutron-deficient uranium isotopes were studied via α spectroscopic methods. A low-lying α-decaying isomeric state was found in ^{218}U. The new isomeric state was assigned spin and parity $I^\pi = 8^+$. The isomer decays by α emission with an energy $E = 10\,678(17)$ keV and with a half-life $T_{1/2} = (0.56^{+0.26}_{-0.14})$ ms. The known alpha-decay properties of the ground state of ^{218}U was measured with improved statistics. The ground-state α-decay has an energy $E = 8612(9)$ keV and a half-life $T_{1/2} = (0.51^{+0.17}_{-0.10})$ ms.

PACS. 23.60.+e α decay – 25.70.Gh Compound nucleus – 27.80.+w $190 \le A \le 219$

The neutron-deficient nucleus ^{218}U is possibly a doubly magic nucleus with $Z = 92$ and $N = 126$, assuming a sub-shell gap at $Z = 92$ between the $h_{9/2}$ and the $f_{7/2}$ proton orbitals. However, recent theoretical calculations by Caurier *et al.* [1] do not support the shell gap theory. While several other $N = 126$ isotones have been studied extensively, for ^{218}U only the α-decay properties of the ground state was known. The occurrence of a low-lying isomeric state in ^{216}Th speaks against the existence of a shell gap. In ^{216}Th [2] an 8^+ state, with a $\pi h_{9/2} f_{7/2}$ configuration, has been found to come low in energy close to the 6^+ state, forming an isomer with a 3% α-decay branch. The discovery of a low-lying isomeric state in ^{218}U [3] would disprove the existence of a shell gap at $Z = 92$.

The experiments were carried out at JYFL cyclotron laboratory. A beam of ^{40}Ar at an energy of $E_{\rm lab} = 186$ MeV was used to bombard a ^{182}W target of 600 μg/cm^2 thickness. The fusion products were separated from the beam particles with the RITU gas-filled separator and implanted into the DSSD of the GREAT spectrometer [4] at the RITU focal plane. The data from two separate experiments, performed one year apart, were analyzed.

The experimental data was analyzed with the GRAIN package [5]. Recoils were correlated with an α-decay in a given position and time window. Correlated mother and daughter alpha-decays were used to form a complete decay chain. In these two experiments a total of 20 of $^{218\rm g}$U, 12 of $^{218\rm m}$U, 5 of ^{219}U and 1 of ^{217}U were identified. The measured production cross-section for ^{218}U was 1.2 nb. The correlated α-α pairs are presented in fig. 1, the uranium isotopes have been indicated.

Table 1. Calculated hindrance factors.

Δl	$^{216\rm m}$Th	$^{218\rm m}$U	^{219}U
0	14000	69000	130
4	2900	15000	24
6	520	2700	4.6
8	20	280	
9	13	73	
10	3	17	
11	0.5	3.4	
12	0.1	0.6	
13		0.1	

The possible spin and parity assignment for the new isomeric state in ^{218}U is either 8^+ or 11^- based on refs. [1,2]. These two assignments are the only ones which are consistent with the experimental α-decay data since the electromagnetic transitions from other levels are too fast for α-decay to compete with. In order to determine the spin and parity of the new isomeric state the method of Rasmussen [6] was applied. Tentatively, the α-decay

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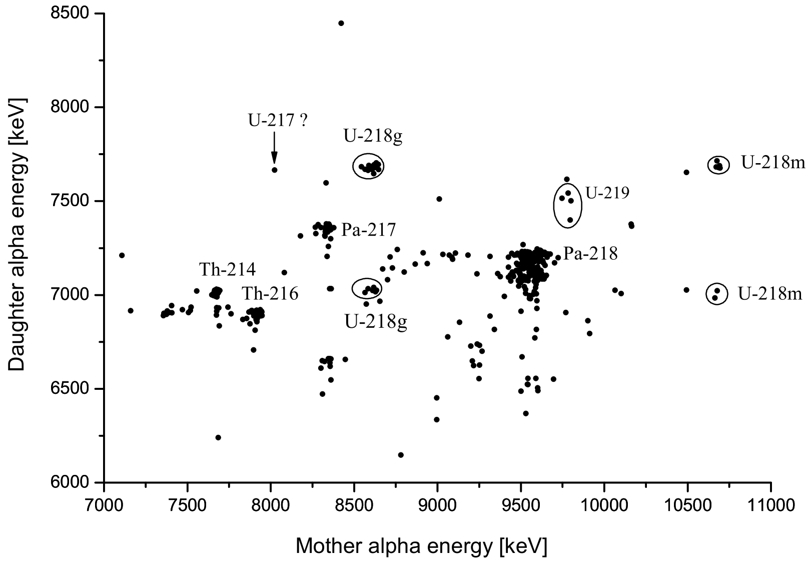

Fig. 1. Correlated α-decay events, plotted as a function of the energies of mother and daughter α-decays. Search time for a mother α was 80 ms and the search time for daughter α was 20 s.

Table 2. Summary of the results obtained in this work.

Nucleus	E (keV)	Half-life (ms)	Cross-section (nb)	No. of events	State
^{217}U	8024(14)	$0.19^{+1.13}_{-0.10}$	0.05	1	$(\frac{1}{2}^-)$
^{218g}U	8612(9)	$0.51^{+0.17}_{-0.10}$	0.9	20	0^+
^{218m}U	10 678(17)	$0.56^{+0.26}_{-0.14}$	0.3	12	8^+
^{219}U	9774(18)	$0.08^{+0.10}_{-0.03}$	0.2	5	$\frac{9}{2}^+$

branch from this level must be very close to 100%. The hinderance factor of the α-decay from the new isomeric state was compared with that found for the 8^+ state in ^{216}Th [2].

The relevant hindrance factors are listed in table 1. The isomeric states in ^{216}Th and in ^{218}U show similar structural behavior. On the basis of this analysis the spin and parity of 11^- were ruled out and an 8^+ assignment was determined for the isomer in ^{218}U. Similarly the Rasmussen method was applied to assign the spin and parity of $9/2^+$ to the ground state of ^{219}U. Interestingly, the half-life of the isomer in ^{218}U agrees with that of its ground state. This is due to the high spin of the decaying isomeric state. All the half-lives and decay energies are presented in table 2.

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