STUDIES OF ^{225,226}U ALPHA DECAY CHAINS* **

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Studies of ^{225,226}U α-decay chains produced via heavy ion induced fusion reactions of ^{22}Ne + ^{208}Pb$\rightarrow$ ^{230}U and of ^{18}O + ^{208}Pb$\rightarrow$ ^{226}Th were carried out using the JYFL gas-filled magnetic recoil separator RITU. The data obtained for α-decays of ^{225,226}U, ^{221,222}Th, ^{218}Ra and ^{213}Rn concerning their α-particle energies, half-lives and α-decay fine structures are compared to previous investigations.

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1. Experiments

Studies of ^{225,226}U α-decay chains were performed using two heavy ion induced fusion evaporation reactions, ^{22}Ne + ^{208}Pb and ^{18}O + ^{208}Pb. The first experiment was employed for the α-particle decay studies of ^{225,226}U and the second for their subsequent daughter α-decay chains. Both beams were delivered from the JYFL K130 heavy ion cyclotron and the separation of fusion products was performed using the gas-filled magnetic recoil separator RITU [1]. The detection of evaporation residues and their decay was based on the use of a position sensitive PIPS Si-detector, where the evaporation residues are implanted and their subsequent decays are measured. In the second experiment also a single Ge-detector was used at the focal plane of

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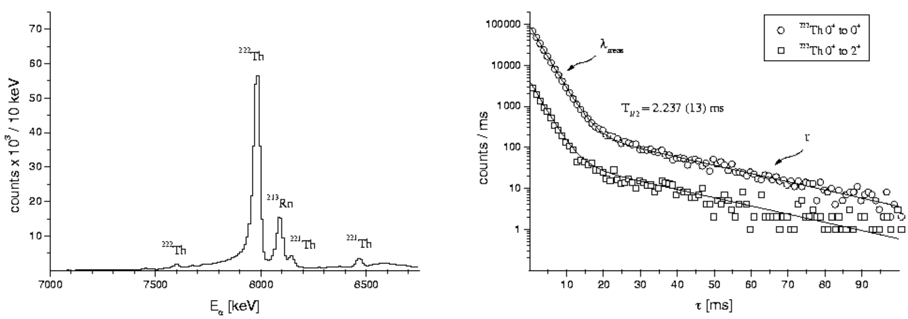
RITU in order to obtain information about the short living α-active nuclei using the α–γ coincidence technique.

2. Results

In the data analysis the correlation method [2] was employed. The energy calibration was based on known α-activities produced in the reactions providing an energy resolution of about 35 keV (FWHM). The relatively poor energy resolution was due to weak cooling of the Si-detector, since with slow recoils it was not possible to use any foils to separate the Si-detector from He-filling gas. The half-life analysis was carried out using recoil-α (Fig. 1) or α-α correlations. There the correlated event pairs can have their origin either in true correlations or in accidental ones. Thus the decay curve for a single activity consists of two components, one for the real correlations ($\lambda_{\rm meas}$) and one for the accidental correlations (r). The true decay constant is extracted using the formula $\lambda = \lambda_{\rm meas} - r$ [3]. As an example, the decay curves of ^{222}Th α-particle decays to both 0^+ and 2^+ states are shown in figure 1.



(a) (b)

Fig. 1. (a) Recoil-α correlations for the ^{18}O + ^{208}Pb reaction at a projectile energy of 92 MeV. (b) Measured lifetime curves for ^{222}Th alpha decays.

The experimental results of ^{225,226}U α-decay chains are expressed in Table I. The data for ^{226}U, ^{222}Th and ^{218}Ra are consistent with previously measured values reported in references [4–6]. In the case of ^{222}Th, a 389.5(5) keV γ-ray transition from 2^+ to 0^+ in ^{218}Ra was observed in coincidence with the known α-decay of ^{222}Th. This transition was also observed in an in-beam γ spectroscopy study [4]. The study of ^{218}Ra is interesting from the point of view of half-life since several values for ^{218}Ra have been published with relatively small error bars varying from 14(2) μs and 15.6(10) μs to the somewhat longer value of 26(2) μs and 25.6(11) μs reported in references [7–10], respectively. The measured half-life in this work is consistent with values reported in [8] and [9].

The data for ^{225}U are consistent with data reported in [11]. Also a new alpha branch with an energy of 7630(20) keV was observed in recoil-α–α–α correlations. However, only two triple-chains assigned to ^{225}U were observed, but the measured energy is consistent with known energy of $(11/2^+)$-state of ^{221}Th observed in an in-beam experiment [12].

TABLE I

α particle energies, intensities and half-lives of ^{225,226}U α-decay chains.

	Present data			Previous data			
Nuclide	E_α [keV]	I_α [%]	$T_{1/2}$ [ms]	E_α [keV]	I_α [%]	$T_{1/2}$ [ms]	Ref.
^{225}U	7867(6)	83(7)	84(4)	7879(15)	85	95(15)	[11]
	7820(20)	15(7)		7821(15)	15		
	7630(20)	2(1)					
^{226}U	7566(4)	85(11)	260(20)	7570(20)	85(5)	200(50)	[4]
	7384(7)	15(5)		7420(20)	15(5)		
^{221}Th	8469(4)	21*	1.73(3)	8472(5)	39(2)	2.8(3)	[12]
	8142(3)	72*		8146(5)	56(3)		
	7732(4)	7*		7733(8)	6(1)		
^{222}Th	7980(2)	97.7(9)	2.237(13)	7982(8)	97(1)	2.8(3)	[5]
	7599(2)	2.3(2)		7600(15)	3(1)		
^{218}Ra	**	**	0.0252(3)	8389(6)	100	0.0256(11)	[6]
^{213}Rn	8090(3)	98.2(12)		8088(8)	99.0(5)	25.0(2)	[13]
	7555(4)	1.0(2)		7553(15)	1.0(5)		
	7254(4)	0.8(2)					

* Errors in intensities are not determined because of high uncertainty due to internal conversion electron summing (see figure 2 and text for details).
** α-particle energy and intensity were not determined because of pile-up of daughter (^{214}Rn, $T_{1/2} = 0.27(2)$ μs [7]) pulses.

The nuclide ^{221}Th is somewhat difficult from point of view of fine structure studies due to rather strong internal conversion. This causes summing of energies of conversion electrons and emitted α-particles. Thus alpha branches for ^{221}Th reported in [12] are difficult to verify from data measured in this work, but α-particle energies can be easily identified (see figure 2, solid line). Possible α-particle energies observed between the known peaks with energies 8142(3) keV and 8469(4) keV can be also explained by sum energy of emitted α-particle and conversion electron. This interpretation is actually supported by Ra X-ray gated recoil-α correlations (dashed line) shown in figure 2. There counts for X-ray gated α-particles are expressed on the right hand side and counts for recoil-α–α correlated ^{221}Th (solid line) are shown on the left hand side. Thus the origin of the α-peaks around 8250 keV and 8375 keV shown in figure 2 remains unverified from the data obtained from these experiments. However, two alpha branches are indeed reported in [14] with energies of 8265(10) keV and 8375(10) keV and intensities of 4 % and 11 %, respectively.

Alpha–γ coincidences were also observed for ^{221}Th. In this study the γ-ray transitions from excited $(7/2^+)$ and $(11/2^+)$ states in ^{217}Ra fed by 8142(3) keV and 8469(4) keV α-particles, respectively, to the ground state were observed. However, γ-ray coincidences with the α-particle decay with energies around 8250 keV and 8375 keV were not observed. This could also mean that the origin of the α-particle decay with energies around 8250 keV and 8375 keV are a result of conversion electron summing.

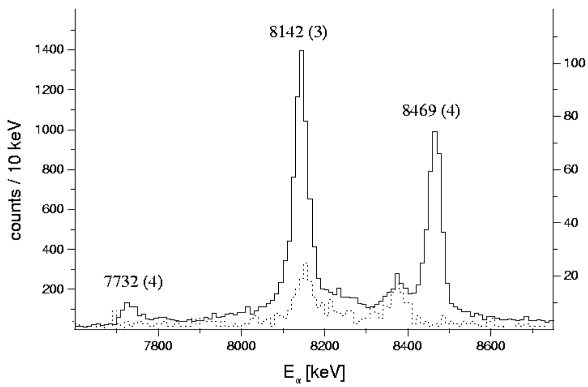


Fig. 2. Recoil-α–α correlated ^{221}Th (solid line) and recoil-α gated by Ra X-rays (dashed line).

The decay of the nuclide ^{213}Rn is more straightforward and the data obtained in this work are consistent with previously published data. Also a new alpha branch with α-particle energy of 7254(4) keV was observed in coincidence with known γ-rays from the $3/2^-$ state of ^{209}Po. Finally, it is worth noting that the α-particle decay properties of ^{217}Ra, ^{214}Rn and ^{209,210}Po which also belong to the decay chains studied were not possible to study because of their unsuitable half-lives from the point of view of electronics or correlation method.

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