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Short note

Beta Decay of ^{111}Tc to ^{111}Ru

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Abstract. The β-decay of the very neutron-rich ^{111}Tc nucleus has been observed. A partial decay scheme of ^{111}Ru is presented, complementing the high-spin levels earlier reported in spontaneous fission work.

PACS. 27.60.+j $90 \leq A \leq 149$ – 21.10.Tg Lifetimes – 23.20.Lv Gamma transitions and level energies

1 Introduction

Neutron-rich even-even Ru isotopes are triaxial nuclei linking the region of strong axial deformations for Sr, Zr, Mo nuclei to the higher-Z region near the Sn shell closure. The low-spin level structure was investigated in β-decay studies [1,2], whereas the high-spin levels were studied both experimentally [3,4] and theoretically [5,6]. Levels in odd-mass Ru isotopes are known from β-decay up to ^{109}Ru [7] and from prompt-fission studies up to ^{111}Ru [8,9] compiled in [10]. Recently, the production of ^{111}Tc was first demonstrated by a β-delayed neutron experiment [11]. Here, we report on levels in ^{111}Ru populated in β-decay of ^{111}Tc providing complementary information to the prompt-fission results.

2 Experiments

The experiment was performed using on-line mass separation of products of proton-induced fission of uranium at the IGISOL facility in Jyväskylä [12]. The mass separated beam was collected on a tape. Long-lived activities were removed at regular intervals. The collection point was viewed by a ΔE-E plastic telescope for the detection of β-particles and two Ge-detectors. Beta-γ and γ-γ coincidence events were recorded. Since ^{111}Tc has Q_β=7.48(8) MeV [13], the highest value of the separated A= 111 isobars, γ-rays were assigned to its decay by gating on the high-energy part of the β-spectrum.

3 Results

The list of γ-rays observed is given in Table 1. Level lifetimes obtained from β-γ-t coincidences by the centroid-shift method are listed in Table 2. Several of the γ-rays from ^{111}Tc were observed in prompt-fission. There is evidence for changing the order of the transitions in the decay of the 317 keV level with respect to [9]. The numerous coincidences of the 150 keV line place it at the bottom of the cascade. The clear 167 keV-150 keV and the weaker 213 keV-104 keV coincidences can be accounted for by an intermediate level at 213 keV. From intensity balance in the 104 gate, the total conversion coefficient of the 63 keV transition is deduced to be 5.8(23), corresponding to M1+E2 (α_{M1}= 1.17, α_{E2}= 6.8) or even pure E2 multipolarities. However, the centroid shift for the 150 keV transition, assuming the 150 keV level prompt, is reproduced if $t_{1/2}(213)$= 6.0 ns, leading to an enhancement of about 380 for the 63 keV transition if a pure E2. This large value favours the alternative M1+E2 multipolarity. The known Z-dependence of isobaric yields [15] allows a rough estimate of the β-ground-state branch. The resulting small value (< 20%) has been neglected in the calculation of logft values. The decay scheme is shown in Fig. 1.

Both the 63 keV and 150 keV transitions [7] are M1, which implies same parity as the $5/2^+$ ground state [16], thus the even one for the 150 and 213 keV levels. Strongly β-fed levels must have the same even parity as the 150 keV level. No lifetime having been reported for the 76 keV transition from the $11/2^-$ level [8,14], it is likely a dipole, resulting in I= 9/2 for the 317 keV level [9]. Lifetimes also favour dipole character for the 104 and 167 keV transitions over pure E2, making the 150 keV level a

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Table 1. List of γ-rays in ^{111}Tc decay. Intensities of transitions seen only in coincidences are calculated according to their proposed placement. [a] M1+E2 (this work), [b] M1 from Ref. [7]

Energy [keV]	Intensity [%]	from	to	Coincidences
63.0 (3)	3.0 (4)	213	150	(104), (150) [a]
103.9 (3)	13.4 (17)	317	213	63, 150
150.2 (2)	92.7 (56)	150	0	63, 104, 167, (173), 206, 219, 392, 713 [b]
166.9 (3)	3.0 (6)	317	150	150
172.6 (3)	2.0 (4)	490	317	63, 104, 150
205.6 (2)	7.2 (8)	(356	150)	150
212.8 (7)	1.0 (5)	213	0	(104)
218.5 (2)	5.8 (6)	369	150	150
279.7 (2)	36.7 (52)	280	0	
368.8 (2)	100 (42)	369	0	
392.1 (3)	2.8 (5)	543	150	(150)
413.8 (5)	2.0 (7)			(104)
542.8 (2)	20.9 (26)	543	0	
571.0 (3)	7.7 (24)	571	0	
616.5 (7)	1.7 (5)	(767	150)	(150)
674.3 (6)	1.2 (4)	(824	150)	(150)
713.2 (5)	2.9 (7)	(863	150)	150
898.2 (5)	1.5 (7)	(1048	150)	(150)
1026.3 (4)	9.5 (20)	1026	0	
1435.2 (5)	14.5 (37)	1435	0	

Table 2. Lifetimes for transitions in ^{111}Ru delayed with respect to β-particles. The timing resolution was 30 ns for the 276 keV transition in ^{111}Pd. [a] The average for the 104 and 167 keV transitions (after correction for the 490 keV level halflife) leads to $t_{1/2}(317)= 4.4(12)$ ns in agreement with 6 ns first reported in [14]

Transition energy [keV]	Measured halflife [ns]	Remarks
104	4.4 ± 1.4	levels 317, 490 keV [a]
150	3.1 ± 0.8	complex, levels 150, 213 and 317 keV
167	6.6 ± 1.9	level 317, 490 keV [a]
173	6.1 ± 1.3	level 490 keV
206	7.8 ± 2.1	tentative level 356 keV
369	7.2 ± 1.6	level 369 keV

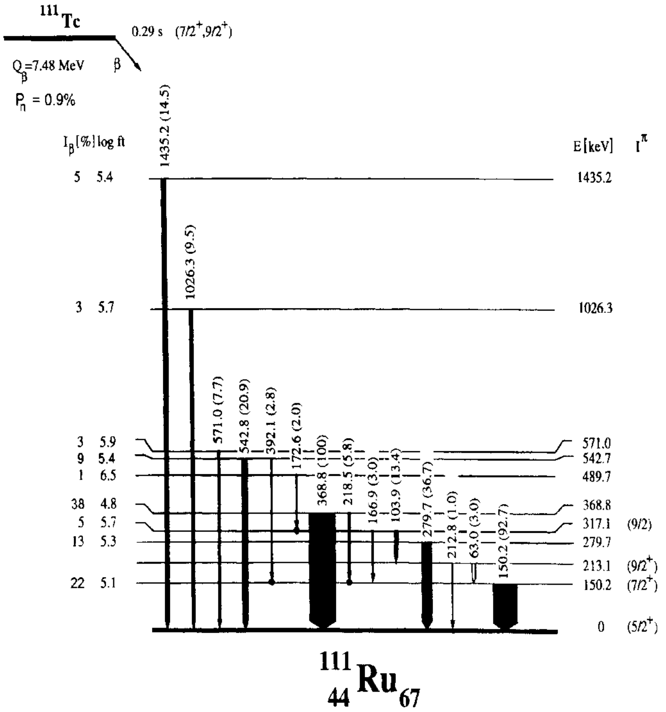

Fig. 1. Decay scheme of ^{111}Tc to ^{111}Ru. $T_{1/2}$, P_n and Q_β values are from Refs. [11,13], respectively

probable 7/2$^+$ level. The weakness of the 213 keV transition with respect to the 63 keV transition is suggestive of $I^\pi(213)= 9/2^+$. The lifetime of the 369 keV transition corresponds to a retarded M1 (6.10^{-5} Weisskopf units) or a slightly hindered E2 transition (0.4 W.u.), resulting in $I^\pi(369)=(5/2, 7/2, 9/2)^+$. Finally, the feedings to the 150 keV (7/2$^+$) state and to the I= 9/2 level at 317 keV, are consistent with $I^\pi= 7/2^+$ or $9/2^+$ for the ground state of ^{111}Tc. In this case, a tentative 76(1) keV transition with $I_\gamma= 0.07(3)$ units could be identified with the one from the 11/2$^-$ level which could be weakly populated.

The strong β-feedings to the levels at 150, 280, 369 and 543 keV are a salient feature of the decay scheme.

Qualitatively, this decay pattern fits into the systematics of decays of ^{110}Mo to ^{110}Tc [17] and ^{112}Ru to ^{112}Rh [18], which have one proton less and more, respectively. The latter have been successfully reproduced by calculations with the IBA model [19]. It would be interesting to extend this model to the odd-mass case.

4 Conclusion

The feeding of levels in ^{111}Ru from the β-decay of the very neutron-rich nucleus ^{111}Tc is reported for the first time. There is only little overlap with the levels fed in prompt-fission. This feature was also observed for the decays of ^{109}Tc [7] and ^{113}Tc [20]. Nevertheless, it is obvious that more detailed investigations are needed in order to gain a deeper understanding of the nuclear structure of ^{111}Ru and of its neighbours.

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