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ALPHA DECAY STUDIES OF TRANSLEAD NUCLEI AT THE PROTON DRIP LINE* **

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Extensive α-decay studies of the very neutron deficient isotopes ^{191}Po, ^{195}Rn, and ^{196}Rn have been performed at the RITU gas-filled recoil separator. The recoil-α–(α) correlation technique and the α–γ coincidence technique have been utilized to unambiguously connect the observed α-decays to proper nuclei. Illustrative examples on how the α-decay can yield spectroscopic information on the nuclei studied will be presented.

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1. Introduction

In this work evaporation residues from the heavy ion induced fusion reactions have been separated from the beam using the JYFL gas-filled recoil separator RITU. In addition to nuclear mass information, α-decay in the Pb region can provide important spectroscopic information on intruder states, shape coexistence and onset of deformation especially when fine structure is observed.

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2. Alpha decay study of ^{191}Po

In the work performed at JYFL [1–3] the neutron deficient ^{191}Po isotope was studied utilizing α-γ coincidence technique. The first experiment to study the fine structure in the α-decay of ^{191}Po was carried out using the fusion evaporation reaction ^{160}Dy(^{36}Ar,5n)^{191}Po [1,2]. Later on a complementary experiment was performed using the reaction ^{142}Nd(^{52}Cr,3n)^{191}Po [3]. In these experiments two α-decaying isomeric states were observed with $E_\alpha = 7334(5)$ keV and $T_{1/2} = 22(1)$ ms ($I_\alpha = 77(3)$ %) assigned to ^{191g}Po and the other $E_\alpha = 7376(5)$ keV and $T_{1/2} = 93(3)$ ms ($I_\alpha = 50(3)$ %) assigned to ^{191m}Po. In addition, α-decay lines with $E_\alpha = 6888(5)$ keV ($I_\alpha = 46(4)$ %) and $E_\alpha = 6966(10)$ keV ($I_\alpha = 8(3)$ %), feeding the γ-decaying excited $\nu i_{13/2}\otimes[\pi(2p-2h)]_{0^+}$ and $\nu p_{3/2}\otimes[\pi(2p-2h)]_{0^+}$ states in ^{187g}Pb and ^{187m}Pb, respectively, were observed. In fact it turned out that the 6888 keV α-decay is unhindered (HF = 0.63) and the 7376 keV α-decay is strongly hindered (HF = 26). The detailed α-decay scheme for ^{191}Po is shown in Fig. 1. An extensive discussion of the ^{191}Po part of the scheme is presented in the references [1–3].

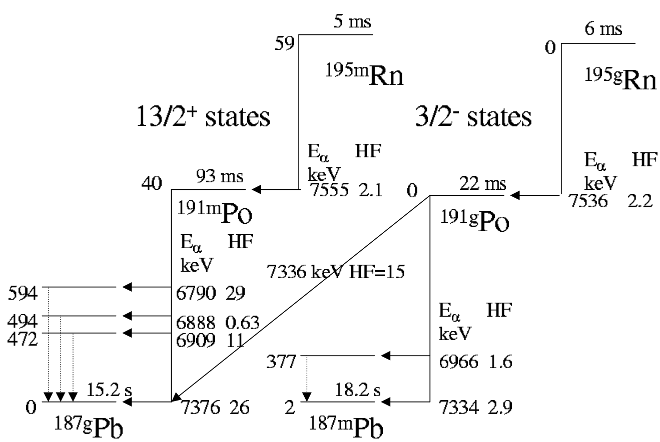

Fig. 1. Level scheme for ^{191}Po and ^{195}Rn and observed hindrance factors HF.

3. Alpha decay study of ^{196}Rn and ^{195}Rn

Fusion evaporation reactions of the type ^{142}Nd(^{56}Fe,xn)$^{198-x}$Rn were used to synthesize neutron deficient Rn isotopes [4]. Altogether 19 ER$-\alpha$-decay chains assigned to the ^{196}Rn isotope were observed. For nine of the chains a full energy daughter decay was also found. The measured decay properties for the daughter activity $E_\alpha = 7167(11)$ keV and $T_{1/2} = (29^{+15}_{-8})$ ms point to ^{192}Po for which $E_\alpha = 7167(7)$ keV and $T_{1/2} = 33.2(14)$ ms [5] have been reported. The decay properties of $E_\alpha = 7461(9)$ keV and

$T_{1/2} = (4.4^{+1.3}_{-0.9})$ ms were determined for the isotope ^{196}Rn. These values are compatible with those reported in [6], where $E_\alpha = 7492(30)$ keV and $T_{1/2} = (3^{+7}_{-2})$ ms are given for ^{196}Rn.

Altogether seven ER$-\alpha_m - \alpha_d$ decay chains, where the mother activity $E_\alpha = 7555(13)$ keV and $T_{1/2} = (3^{+2}_{-1})$ ms was followed by daughter activity $E_\alpha = 6878(12)$ keV and $T_{1/2} = (110^{+70}_{-30})$ ms, were observed. In addition eleven ER$-\alpha_m - \alpha_d$ decay chains where the mother activity $E_\alpha = 7536(11)$ keV and $T_{1/2} = (6^{+3}_{-2})$ ms was followed by daughter activity $E_\alpha = 7331(11)$ keV and $T_{1/2} = (15^{+7}_{-3})$ ms, were found. Finally, three decay chains, where the mother activity $E_\alpha = 7555(20)$ keV and $T_{1/2} = (9^{+12}_{-4})$ ms was followed by an activity with $E_\alpha = 7364(20)$ keV and $T_{1/2} = (95^{+130}_{-60})$ ms, were identified. The measured decay properties for the daughter activities are compatible with those reported for ^{191}Po (see above). Based on these the decay properties of $E_\alpha = 7555(11)$ keV and $T_{1/2} = (5^{+3}_{-2})$ ms (^{195m}Rn) and $E_\alpha = 7536(11)$ keV and $T_{1/2} = (6^{+3}_{-2})$ ms (^{195g}Rn) can be proposed to belong to the new nuclide ^{195}Rn.

4. Discussion

Through systematic study of α-decay hindrance factors HF and reduced widths δ^2 some structure information on the decaying states can be deduced. As can be seen from the level scheme (Fig. 1) although the α-decay energy of the $13/2^+$ isomeric state in ^{191}Po is slightly higher than the decay energy of the $3/2^-$ ground state, its half-life is nearly 5 times longer. On the other hand, the existence of the unhindered (HF = 0.63) decay to the excited oblate $13/2^+$ state in ^{187g}Pb points to a deformed $13/2^+$ isomeric state in ^{191}Po. This has been interpreted as a weak coupling of the odd neutron to an intruder deformed 0^+ state in the even–even core. The situation is completely different from the α-decay of the $3/2^-$ ground state in ^{191}Po, where the feeding of the $3/2^-$ isomeric state and the excited $3/2^-$ state have equal strengths.

The hindrance factors determined for ^{195m}Rn and ^{195g}Rn lead to the conclusion that the α-decays occur between states of equal spin, parity and configuration. Thus the α-decay with the energy 7536 keV originates from the $3/2^-$ ground state of ^{195}Rn and the α-decay with the energy 7555 keV originates from the $13/2^+$ isomeric state of ^{195}Rn as illustrated in Fig. 1.

The reduced α-decay widths for neutron deficient even-mass Po, Rn and Ra isotopes, including ^{196}Rn studied in this work, are shown in Fig. 2. The reduced α-decay widths of even-mass Po isotopes with neutron numbers $112 \leq N \leq 126$ increase smoothly with decreasing neutron number. The reduced widths for the ground state to ground state transitions remain constant for $^{190-196}$Po and decrease markedly for ^{188}Po. The reason for this

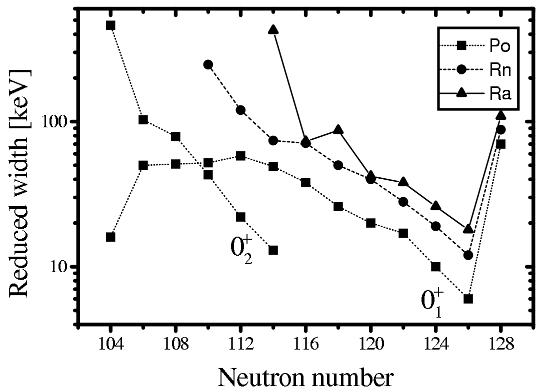

Fig. 2. Reduced width values for Po, Rn and Ra nuclides.

is that the α-decays from the ground state to 0^+ intruder states in Pb are getting more favorable. This feature can be seen in Fig. 2 where also reduced widths for decays between the ground state and two particle two hole $\pi(2p-2h)$ proton intruder states are shown. An interpretation has been given that the ground states of neutron deficient Po isotopes starting from ^{194}Po are mixed with different configurations, spherical $\pi(2p-0h)$, oblate $\pi(4p-2h)$ (and prolate $\pi(6p-4h)$), and therefore the ground states of these nuclei are deformed. The reduced α-decay widths of even-mass Rn isotopes with neutron numbers of $114 \leq N \leq 126$ increase smoothly with decreasing neutron number. The reduced α-decay width value for ^{198}Rn is slightly higher and the α-decay of ^{196}Rn is clearly faster than the smooth behavior predicts. In the latter case the α-decay could be considered to take place between the mixed deformed 0^+ ground state in ^{196}Rn and mixed deformed 0^+ ground state in ^{192}Po. This is in good agreement with results from recent γ-ray studies where the same kind of intruder structures were exposed in ^{198}Rn, ^{194}Po, and ^{192}Po [7, 8].

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