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

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Extensive $\alpha$-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-$\alpha$–($\alpha$) correlation technique and the $\alpha$–$\gamma$ coincidence technique have been utilized to unambiguously connect the observed $\alpha$-decays to proper nuclei. Illustrative examples on how the $\alpha$-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, $\alpha$-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 $\alpha$-$\gamma$ coincidence technique. The first experiment to study the fine structure in the $\alpha$-decay of $^{191}$Po was carried out using the fusion evaporation reaction $^{160}$Dy($^{36}$Ar,5$n$)$^{191}$Po [1,2]. Later on a complementary experiment was performed using the reaction $^{142}$Nd($^{52}$Cr,3$n$)$^{191}$Po [3]. In these experiments two $\alpha$-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, $\alpha$-decay lines with $E_\alpha = 6888(5)$ keV ($I_\alpha = 46(4)$ %) and $E_\alpha = 6966(10)$ keV ($I_\alpha = 8(3)$ %), feeding the $\gamma$-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 $\alpha$-decay is unhindered (HF = 0.63) and the 7376 keV $\alpha$-decay is strongly hindered (HF = 26). The detailed $\alpha$-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].

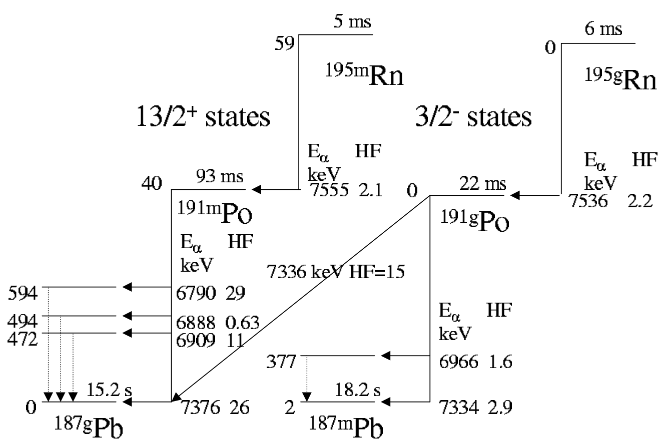


Fig. 1. Level scheme for $^{191}$Po and $^{195}$Rn and observed hindrance factors HF.

## 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 $\alpha$-decay hindrance factors HF and reduced widths $\delta^2$ some structure information on the decaying states can be deduced. As can be seen from the level scheme (Fig. 1) although the $\alpha$-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 $\alpha$-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 $\alpha$-decays occur between states of equal spin, parity and configuration. Thus the $\alpha$-decay with the energy 7536 keV originates from the $3/2^-$ ground state of $^{195}$Rn and the $\alpha$-decay with the energy 7555 keV originates from the $13/2^+$ isomeric state of $^{195}$Rn as illustrated in Fig. 1.

The reduced $\alpha$-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 $\alpha$-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

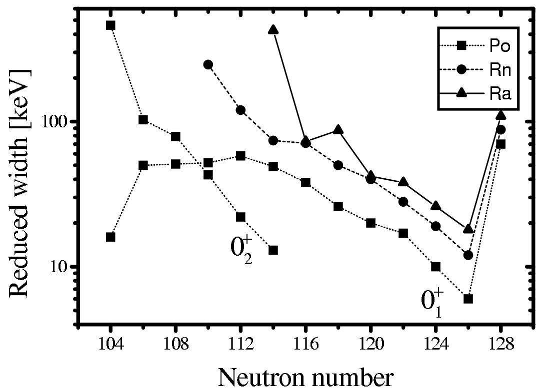


Fig. 2. Reduced width values for Po, Rn and Ra nuclides.

is that the $\alpha$-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 $\alpha$-decay widths of even-mass Rn isotopes with neutron numbers of $114 \leq N \leq 126$ increase smoothly with decreasing neutron number. The reduced $\alpha$-decay width value for $^{198}$Rn is slightly higher and the $\alpha$-decay of $^{196}$Rn is clearly faster than the smooth behavior predicts. In the latter case the $\alpha$-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 $\gamma$-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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