THE NEW ISOTOPES IN Po–Rn REGION*

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This contribution reviews the results of the recent experiments at the velocity filter SHIP in GSI Darmstadt obtained in the region of neutron deficient isotopes from lead to radon. The data for new very neutron-deficient isotopes ^{187}Po, ^{193,194}Rn and their decay properties are presented. The isotopes were produced and identified in the complete fusion reactions ^{46}Ti+^{144} Sm→^{187}Po+3n and ^{52}Cr+^{144}Sm→^{194,193} Rn+2,3n.

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1. Introduction

The strong ground-state (g.s.) deformation of the isotopes above the closed proton shell $Z = 82$ in the vicinity of neutron mid-shell at $N = 104$ has been predicted for long time already. In the case of very neutron deficient polonium isotopes the expected g.s. deformation should change from $\beta_2 = -0.2$ (^{192}Po) to $\beta_2 = 0.311$ (^{187}Po and ^{186}Po). For the very neutron deficient radon isotopes g.s. deformation changes should be even stronger — from $\beta_2 = -0.240$ (^{194}Rn and ^{195}Rn) to $\beta_2 = 0.349$ (^{190}Rn) [1]. Such strong deformation changes in the rather small part of the nuclide chart makes this region unique for the nuclear structure research.

Due to low production cross-section in this region of nuclei (less than 1 nb), the use of traditional in beam technique is currently impossible. On the other hand, α spectroscopy was found to be powerful tool for nuclear structure research in this region (see *e.g.* the references in [2]). Our present study extends this work to even more neutron deficient region by synthesis of new — very neutron deficient — isotopes ^{187}Po, ^{194}Rn and ^{193}Rn.

2. Experimental setup

The experiments were performed at the velocity filter SHIP in GSI, Darmstadt. The pulsed ^{46}Ti and ^{52}Cr beams (5 ms on/ 15 ms off) were delivered by the UNILAC accelerator with a typical intensity of ~ 200 pnA for ^{46}Ti beam and $\sim$ 500–700 pnA for ^{52}Cr, respectively. The target thickness of ^{144}Sm was $400\mu\mathrm{g/cm}^2$. The detector setup, calibrations and more details about the target system are described elsewhere [2, 3].

3. Results

3.1. Synthesis of the new isotope ^{187}Po

The main data for ^{187}Po were collected at the beam energy of 224(1) MeV in the complete fusion reaction of ^{46}Ti+^{144}Sm. The α decay of ^{187}Po was identified using the time and position correlations between the recoil implantation and the α decay of its daughter products (see Fig. 1(b)), an example of one of the observed decay chains). The ^{187}Po decays via α decay of $E_\alpha = 7528(15)$ keV and half-life of $T_{1/2} = 1.40(25)$ ms.

In coincidence with the α decay of $E_\alpha = 7528$ keV we found γ transitions of $E_\gamma = 286(1)$ keV. This indicates population of an excited level in the ^{183}Pb at $E_{\mathrm{exc}} = 286$ keV. The expected g.s.–g.s. transition remains unobserved. Assuming the unhindered nature of 7528 keV ($\delta^2_\alpha = 107(25)$ keV) the limit for the HF of "missing" g.s.–g.s. transition was obtained to be HF$>$ 360 ($\delta^2_\alpha < 0.3$). The proposed decay scheme for ^{187}Po is shown in Fig. 1 (a). More detailed discussion can be found elsewhere [2].

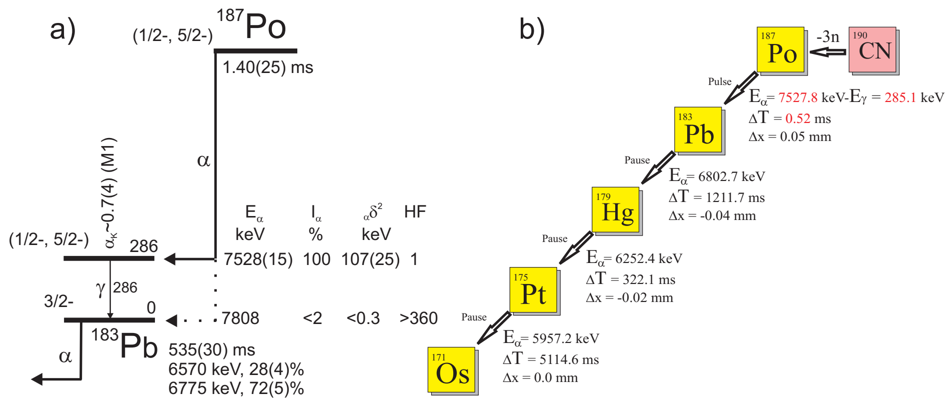

Fig. 1. (a) The proposed decay scheme for ^{187}Po. (b) The example of found decay chain of ^{187}Po.

3.2. Synthesis of new the isotopes ^{193}Rn and ^{194}Rn

The new isotopes ^{193}Rn and ^{194}Rn were produced in complete fusion reaction ^{52}Cr+^{144}Sm. The data were collected at the beam energy of 232(1) MeV for ^{194}Rn and 252(1) MeV for ^{193}Rn, respectively.

For ^{194}Rn we detected altogether 26 α decays with the energy of $E_\alpha =$ 7700(10) keV and half-life of $T_{1/2} = 0.78(16)$ ms. This transition is considered as unhindered since the reduced alpha width is $\delta^2_\alpha = 267(58)$ keV which continues a smooth increasing trend of the reduced alpha width in the lightest radon isotopes.

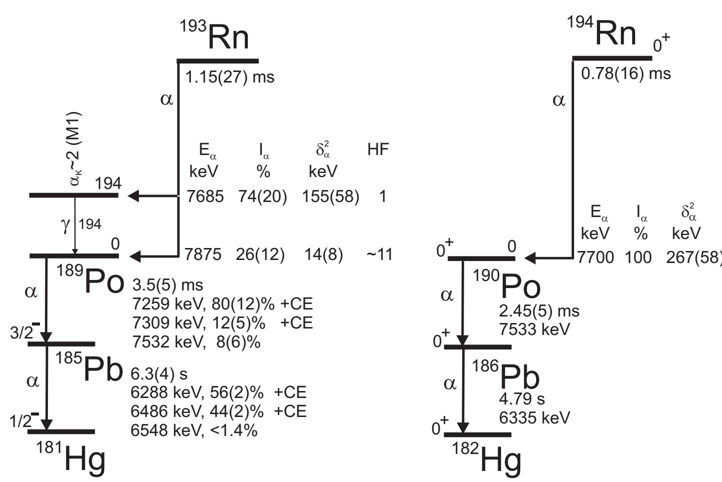

Fig. 2. The proposed decay schemes for ^{194}Rn and ^{193}Rn.

In case of ^{193}Rn we obtained more complex decay pattern. Two peaks of $E_{\alpha 1} = 7685(15)$ keV and $E_{\alpha 2} = 7875(20)$ keV were identified and assigned as a decay of new isotope ^{193}Rn. In coincidence with some of the 7685 keV α decays the 194 keV γ transitions or polonium X-rays were detected. This allows us to assign the 7685 keV α decay as a transition to the excited level at 194 keV as it is drawn in Fig. 2. We measured the half-life of $T_{1/2} = 1.15(27)$ ms and reduced alpha widths of $\delta_\alpha^2 = 155(58)$ keV for the 7685 keV decay and $\delta_\alpha^2 = 14(8)$ keV for the 7875 keV decay. Due to the uncertainties with J^π assignment for ^{189}Po, we prefer not to speculate on the possible spin and parity. Detailed discussion on these isotopes will be published elsewhere [3].

4. Discussion

Despite that the spin and parity can not be unambiguously assigned for these new isotopes, the data for ^{193}Rn and ^{187}Po gives important information about their structure. The unobserved g.s.–g.s. decay for the ^{187}Po with large hindrance factor (HF$>$ 360) suggests large structure difference between the g.s. of ^{183}Pb and ^{187}Po. Since the ^{183}Pb g.s. has a spherical shape with the spin of $3/2^-$ [4] the g.s. of ^{187}Po has to be deformed — most probably prolate. More detailed discussion about the ^{187}Po decay is presented elsewhere [2]. Also in case of ^{193}Rn the g.s.–g.s. transition is hindered by HF= 11 compared to the decay to the excited state. This differs from the decay pattern of the heavier odd-A $^{195-211}$Rn isotopes, which might again indicate the configuration change in ^{193}Rn. More detail discussions including the α decay systematics for radon isotopes might be found in [3].

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