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Short Note

Determination of the Partial Electron Capture- and Spontaneous-Fission Half-Lives of ^{254}No

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Abstract

The isotope ^{254}No was produced in the fusion reaction ^{48}Ca + ^{208}Pb. Using the velocity filter SHIP and radiochemical techniques it was found that the nuclide ^{254}No with a half-life of 55 s decays by α, EC, and spontaneous-fission. Deduced partial half-lives are (61 $\pm$ 2) s for α-decay, (550^{+370}_{-160}) s for EC and $[2.2^{+2.0}_{-1.0}] \times 10^4$ s for spontaneous fission.

The spontaneous-fission half-lives of even-even trans-plutonium nuclides exhibit a pronounced maximum at the neutron number N = 152. For elements beyond lawrencium (Z = 103), however, this effect disappears completely [1], see Fig. 1. It is assumed, that this is caused by a change in the structure of the fission barriers, being double humped for Z $\leq$ 102 and single humped for Z $\geq$ 104 [2]. However, for the last nuclide which exhibits this shell effect, ^{254}No, only a lower limit of about 10^5 s for its spontaneous-fission half-life is known. This value was deduced from the fusion experiments ^{15}N + ^{243}Am [3,4] and ^{13}C + ^{245}Cm [5] where no fission decay from ^{254}No was observed.

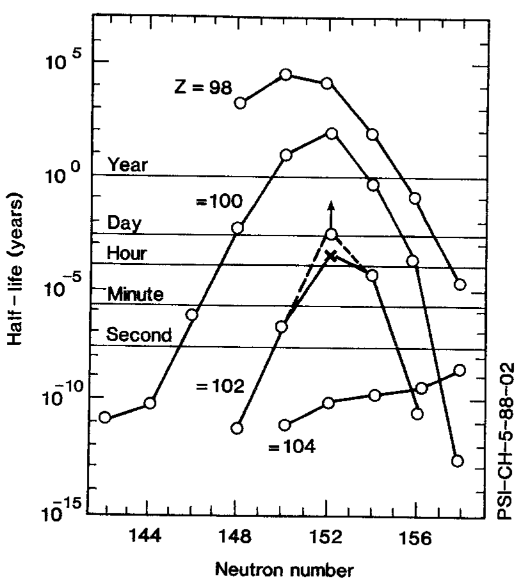

Figure 1: Experimental spontaneous-fission half-lives for even-even nuclides (circles, from [1]). The cross shows our result for ^{254}No.

We have produced ^{254}No in the reaction ^{208}Pb(^{48}Ca,2n)^{254}No at the UNILAC accelerator at GSI. For separation of fusion products from the primary beam and other reaction products the velocity filter SHIP [6] was used. A rotating target wheel equipped with 0.38 mg/cm^2 metallic ^{208}Pb targets on 40 μg/cm^2 carbon backings was bombarded by typically 5 $\times$ 10^{11} p/s of ^{48}Ca. The separated products were implanted into an array of position sensitive surface barrier detectors and assayed for α- and spontaneous-fission decay [7]. The maximum cross section for the production of ^{254}No was found to be about 3.0 μb at a projectile energy of 4.50 MeV/u [8]. During the experiment, a total number of 1615 α-events assigned to

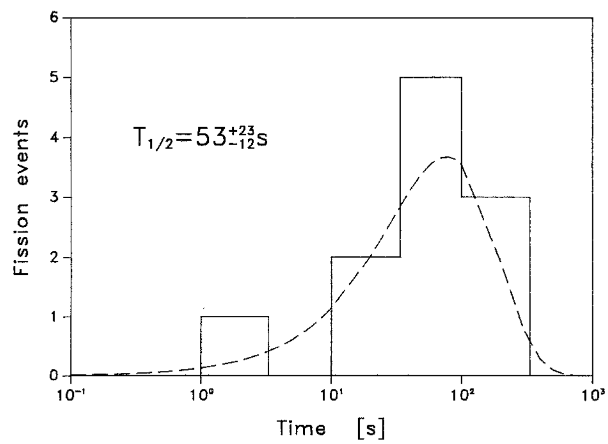

Figure 2: Time distribution (differences between implantation and decay) for the 11 fission events measured with the surface barrier detectors of SHIP in the bombardment of 4.5 MeV/u ^{48}Ca on ^{208}Pb. The indicated half-life of 53 s is determined by the method given in Reference [9]. The dashed line represents the theoretical distribution for $T_{1/2}$ = 53 s.

the decay of ^{254}No and 11 fission events were accumulated. The time distribution of the fission events is shown in Fig. 2. Using the method described in [9], for these 11 events a half-life of (53^{+46}_{-24}) s is deduced at a 95 % confidence level, in good agreement with the literature value for the ^{254}No half-life of 55 s. We did not find any fission from the 0.28 s isomer of ^{254}No, in agreement with theoretical predictions [10]. During the SHIP-bombardment, a long-lived alpha-activity, possibly due to ^{254}Fm, was found. This is indicative of an EC-branch of ^{254}No to ^{254}Md, which then decays by EC to ^{254}Fm. First evidence for an EC-decay branch of ^{254}No has already been reported previously [11]. We have therefore performed a chemistry experiment to determine the production cross section of ^{254}Fm. The same irradiation conditions were used as for the SHIP experiment, however, the products recoiling out of the ^{208}Pb target were collected in a Ni catcher foil. After bombardment this foil was chemically processed. The Cf and Fm fractions were separated from other actinides elements by using a liquid-liquid chromatographic technique with di-2-ethyl-hexyl-orthophosphoric acid (HDEHP) as stationary phase and were then electroplated on Ta-discs for α- and fission-decay counting. Following the decay of the measured α-peak at 6.75 MeV, ^{246}Cf as a granddaughter of ^{254}No was identified in the Cf fraction. In the Fm fraction the isotopes ^{255}Fm and ^{254}Fm were identified from their α-energy and half-lives. ^{255}Fm is the EC-decay product from ^{255}No, formed in the ^{208}Pb(^{48}Ca,1n)^{255}No reaction, however, produced with a much lower cross section than ^{254}No from the 2n reaction [8]. This radiochemical experiment was repeated at two other projectile energies, 4.34 and 4.42 MeV/u. It was found that the ratio between the cross sections of ^{254}Fm and ^{246}Cf did not vary with the bombarding energy, which we consider as a proof that the ^{254}Fm activity observed is indeed produced from an EC-decay branch of ^{254}No.

From the measured α- and spontaneous-fission activities of ^{254}No from the SHIP run and the activities of ^{246}Cf and ^{254}Fm from the chemistry run we deduce the following branches for the decay channels of ^{254}No: (90 ± 4) % for α, (10 ± 4) % for EC, and ($0.25^{+0.20}_{-0.11}$) % for spontaneous-fission decay. The errors given represent mainly statistical uncertainties from the count rates at a 95 % confidence level. Our EC-branch is in good agreement with [11]. The decay branches as given above lead to the partial half-lives of (61 ± 2) s, (550^{+370}_{-160}) s, and $\left[(2.2^{+1.8}_{-1.0})\right] \times 10^4$ s, respectively, for the α, EC, and spontaneous-fission decay channels. Theoretical estimates of the EC-decay half-life using the formalism given by Takahashi [13] give values of 1300 s or 500 s, respectively, if the mass tables of Liran and Zeldes [12] or Møller and Nix [14] are used. Our value for the spontaneous-fission half-life of about 2×10^4 s is significantly lower than the literature values of $\geq 9.4 \times 10^4$ s from Flerov et al. [3] or $\geq 1.1 \times 10^5$ s from Sommerville et al. [5]. At present we have no explanation for this discrepancy. Our value also shown in Fig. 1 is indicating that the effect of the N = 152 shell on the spontaneous-fission half-life for No is not as pronounced as believed so far. However, theoretical calculations of spontaneous-fission half-lives are yet far from reaching an accuracy better than several orders of magnitude. Theoretical estimates for ^{254}No given in the literature range from about 10 s to 21 y [2,10,13,14].

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