EVIDENCE FOR ISOMERIC STATES IN ^{261}Rf

R. Dressler (PSI), A. Türler (Univ. Bern & PSI)

Evidence for a new isomeric state ^{261}Rf was extracted from experimental data of ^{277}112 and ^{269}Hs decay. The α-decay energy of 8.5 MeV and half-live of 4.1 s fits well with decay-energy half-live systematic and suggest that this new state is actually the ground state. A spontaneous fission branch of 40 % can be extracted. Implications for the decay properties of ^{266}Sg are discussed.

The element 112 was discovered by the SHIP group at GSI in 1996 [1]. Up to now three decay chains of the isotope ^{277}112 were observed [2]. At least two of them exhibit very uncommon decay properties of ^{261}Rf as a member of the decay chains. In Tab. 1 the decay properties of these chains starting with ^{269}Hs down to ^{261}Rf are given.

During the first ever chemical investigation of the element Hs [3] three decay chains of ^{269}Hs were observed. This isotope is like ^{261}Rf a member of the ^{277}112 decay chain. All of the Hs events show similar surprising decay properties for ^{261}Rf as observed in the 112 experiments (see Tab. 1).

Table 1: Partial decay chains of ^{277}112 and ^{269}Hs taken from [1-3] (esc denotes escape-events).

		[1]	[2]	[3]	[3]	[3]
^{269}Hs	E [MeV]	9.23	9.18	9.18	8.88	9.10
	τ [s]	19.7	22.0	--	--	--
^{265}Sg	E [MeV]	esc	esc	8.69	8.90	8.68
	τ [s]	7.4	18.8	4.42	17.1	9.32
^{261}Rf	E [MeV]	8.52	SF	8.50	8.50	SF
	τ [s]	4.7	14.5	2.36	0.84	7.92

Therefore, both experiments are in contradiction to the up to now known decay properties of ^{261}Rf. B. Kadkhodayan [4] determined its half-live to be 78^{+11}_{-6} s and established an upper limit for the spontaneous fission (SF)-branch of 11 %, whereas Yu.A. Lazarev [5] showed that ^{261}Rf decays by emission of α-particles with energy of 8.28±0.03 MeV with more than 98 %. In all of these investigations ^{261}Rf was produced directly using heavy ion induced fusion reactions.

S. Cwiok and collaborators calculated single-particle Nilsson levels using the Hartree-Fock-Bogoliubov method with a Skyrme force and a pairing interaction proposed by Lipkin and Nogami [6]. In Tab. 2 the results for the ground state and some of the first excited levels of ^{269}Hs, ^{265}Sg, ^{261}Rf, and ^{257}No are given [7].

Table 2: Single-particle Nelsson levels taken from [7] (g.s. ground-state).

Nilsson level	Excitation energy [MeV]			
	^{269}Hs	^{265}Sg	^{261}Rf	^{257}No
$11/2^-$ [725]	g.s.	g.s.	0.3234	0.6985
$9/2^+$ [615]	0.0945	0.0714	0.4266	0.8709
$7/2^+$ [615]	0.4339	0.0156	g.s.	0.1253
$3/2^+$ [622]	0.7219	0.4337	0.2422	g.s.

Due to the parity and spin conservation during the α-decay, the most probable transition connects states with the same quantum numbers. Two different decay paths of ^{269}Hs can be distinguished, which differ in the opposite parity of the involved states. These paths are given in Fig. 1 in a schematic way.

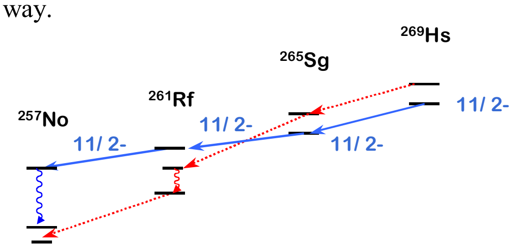

Fig. 1: Schematic view of the decay paths of ^{269}Hs

If the transition between the $11/2^-$ states of Rf and No are assigned to the known decay properties of ^{261}Rf, for the $7/2^+$ ground state decay an α-energy of 8.53 MeV can be extracted, which is close to the observed value. A half-live of $4.2^{+4.1}_{-1.1}$ s (68 % confidence) results from all events, whereas the α-branching is only 60 %.

These decay properties fit well with the half-life predictions by B. Buck [8], which takes into account the spin states. For the ground state transition with 8.52 MeV a half-life of 7.32 s and for the isomeric state with 8.28 MeV a half-live of 74.9 s was calculated. Both predictions are in good agreement with the experimental data and therefore, support the assignment to different isomeric states.

These decay properties of ^{261}Rf alter the view of some older experimental results. In [9] all known decay chains of ^{266}Sg were used to determine the α-decay properties of this isotope. A probability analysis leads to two roughly equal strong α-lines at 8.59 MeV and 8.72 MeV, which is a surprising result for an even-even nucleus. However, the assignment to the decay of ^{266}Sg based only on the assumed decay pattern of a high energetic α-particle shortly followed by a SF-event. From the discussion above follows, that the decay of ^{265}Sg can exhibit such a pattern if the decay starts from an even parity state in ^{265}Sg. So, it is highly possible that in this case the high energetic α-line originate from ^{265}Sg.

REFERENCES

[1] S. Hofmann et al., Z. Phys. **A 354**, 229 (1996).
[2] S. Hofmann et al., Rev. Mod. Phys. **72** (2000).
[3] Ch. Düllmann et al., this Annual Report.
[4] B. Kadkhodayan et al., Radichim. Acta **72**, 169(1996).
[5] Yu.A. Lazarev et al., Phys. Ref. **C 62**, 064307 (2000).
[6] S. Cwiok et al., Phys. Rev. Lett. **83**, 1108 (1999).
[7] W. Nazarewicz, private communication 2001.
[8] B. Buck et al., J. Phys. **G 18**, 143 (1992).
[9] R. Dressler et al.: Ann. Rep. Univ. Bern & PSI 1999, p. 6)