Observation of ^{270}Hs in the complete fusion reaction ^{36}S+^{238}U*

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Superheavy elements ($Z\geq104$) exist only due to nuclear shell effects. Deformed shell closures at Z=108 and at N=162 have been predicted theoretically [1] and observed in recent experiments [2]. Three hassium isotopes, $^{269-271}$Hs, have been produced in the complete fusion reaction ^{248}Cm(^{26}Mg, xn)$^{274-x}$Hs at the linear accelerator UNILAC at GSI [2,3]. The excitation function measurement at five different beam energies resulted in maximum cross sections of the 3n, 4n, 5n exit channels of a few pb.

Recent theoretical studies, analysing the formation of ^{270}Hs in the 4n channel, using a two-parameter Smoluchowski equation, predict even higher cross sections for the reaction ^{238}U(^{36}S,4n)^{270}Hs and ^{226}Ra(^{48}Ca,4n)^{270}Hs in the order of a few tens of pb [4]. Due to a lower reaction Q-value, these calculations predict a maximum cross section of about 24 pb for the ^{238}U(^{36}S,4n)^{270}Hs reaction, while the HIVAP code [5] predicts a maximum cross section of 3.5 pb.

Here, we report on first results of an experiment aimed to study the nuclear fusion reaction ^{36}S + ^{238}U, leading to the compound nucleus ^{274}Hs*. For the experiment we used our highly efficient chemical separation and detection system COMPACT which was connected to a Recoil Chamber (RC) installed behind the ARTESIA target wheel in cave X1 [2]. A beam of $^{36}S^{5+}$ ions was accelerated by the UNILAC up to 7.13 MeV/u and impinged on a rotating ^{238}U target wheel. During the experiment, we used two different sets of ^{238}U targets. The beam passed through a 20.2 µm Be vacuum window, 6 mm of He/O_2 gas mixture (He:O_2 = 9/1), a 12.6 µm Be target backing before entering the ^{238}U target (3 segments of 1.8 mg/cm^2, 1.5 mg/cm^2 and 1.6 mg/cm^2). The second target set had a Be backing of 8.2 µm and 3 segments containing 1.0 mg/cm^2 of ^{238}U each. We assumed that only Hs nuclei with a minimum residual range after exiting the target of 10 mm in gas could be transported to the detection system, corresponding to an active layer of the target of 1.0 mg/cm^2. The energy of the ^{36}S ions was in the range of 175.0 MeV to 181.2 MeV within the first set of target and in the range of 190.4 MeV to 196.1 MeV in the second set [6], corresponding to excitation energies, E*, of 38±3 MeV and 51±3 MeV [7], near the predicted maxima of the 4n and 5n evaporation channel, respectively. Starting at E*= 38 MeV we irradiated the first target set with a beam dose of $5.74\cdot10^{17}$ ions. The second target set was irradiated with a beam dose of $1.03\cdot10^{18}$ ions at E*= 51 MeV.

The data analysis revealed one correlated chain at the higher E* of 51 MeV. A 9.02±0.05 MeV α-particle was observed in bottom detector #24 followed after 23 ms by one 41 MeV spontaneous fission fragment measured in the top detector #24. Due to the measured properties we attributed this decay chain to the decay of ^{270}Hs produced in the 4n evaporation channel [2].

Because of background from α-decay and SF of heavy nuclides (A>200) from (multi) nucleon transfer pseudo correlated chains can be found with nonzero probability. We have searched for possible random decay chains α·α·α·α, α·α·SF and α·SF, using subsequent time windows of 300 s length each. α-particles in an energy window $8.0 \leq E_\alpha \leq 9.5$ MeV and SF-like events with at least one fragment above a threshold of 15 MeV were considered. 351 and 771 α-particles have been registered in the first and the second run, respectively. Mainly this background was attributed to α-decays of ^{212}Po. In addition, 6 SF-like events were registered in the first run and 13 events in the second run. None of these high energy events were correlated in time and position to each other. The results are shown in Table 1.

Table 1: Random rates for different decay chains

decay chain	E* = 38 MeV	E* = 51 MeV
α·α·α·α	$7.08\cdot10^{-4}$	$3.12\cdot10^{-3}$
α·α·SF	$4.61\cdot10^{-3}$	$1.67\cdot10^{-3}$
α·SF	$1.6\cdot10^{-2}$	$4.6\cdot10^{-2}$

At E*= 38 MeV the cross section limit for both channels is 2.9 pb. The cross section for the 4n channel at E*= 51 MeV based on the one event is $0.8_{-0.7}^{+2.6}$ pb and the cross section limit for the 5n channel is 1.5 pb. Errors and limits correspond to 68% confidence level. The measured cross section and cross section limits are lower than for the reaction ^{248}Cm(^{26}Mg,xn)$^{274-x}$Hs [3], especially for 5n evaporation channel, in contrast to calculations made in [4]. We plan to continue these measurements in the near future.

References

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* Work supported by BMBF project 06MP247I
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