TASCA Commissioning Completed*

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The **T**rans**A**ctinide **S**eparator and **C**hemistry **A**pparatus (**TASCA**) project [1], which is focusing on the separation and investigation of neutron-rich transactinide nuclides produced in actinide-target based reactions, has successfully finished its commissioning; see [2] for an interim report. TASCA is ready for the envisioned research program which includes both chemical investigations of transactinide or superheavy elements (SHE) after preseparation with the gas-filled separator and nuclear structure and nuclear reaction studies.

The central device of TASCA is a gas-filled separator in a DQQ configuration operated either in the "High Transmission Mode" (HTM, DQ_hQ_v) or in the "Small Image Mode" (SIM, DQ_vQ_h) [1-5]. In the HTM, the unsurpassed transmission of TASCA - at a relatively low dispersion - is exploited. In contrast, the SIM provides unique possibilities due to its small spot size in the focal plane (< 3 cm diam.) at a still relatively high transmission; see Table 1.

Table 1: Important parameters of TASCA, calculated for the reaction ^{48}Ca(^{244}Pu,3n)^{289}114, in comparison with other gas-filled separators operated in SHE research.

Separator	Con-figur-ation	Trans-mission %	Dis-persion mm/%	Bρ (max) Tm
DGFRS	DQ_hQ_v	35	7.5	3.1
GARIS	DQ_hQ_vD	40	9.7	2.16
BGS	Q_vD_hD	49-59	20	2.5
TASCA	DQ_hQ_v	60	9	2.3
TASCA	DQ_vQ_h	35	1	2.3

Table 2 provides a compilation of all nuclear reactions and reaction products applied and detected in the course of the commissioning program together with the mode TASCA was operated in and the fill gas. Also listed are experiments to test and optimize the recoil transfer chambers (RTC) [6], the gas-jet transport of preseparated products into our Rotating wheel On-line Multidetector Analyzer (ROMA), and its performance, and the coupling and use of aqueous chemistry set-ups behind TASCA.

Table 2: Nuclear reactions and their products used to commission TASCA; H=HTM, S=SIM, TSp=TASISpec, R=ROMA, C=chemistry, catch=catcher foils.

Product	xn	Beam	Target	Mode	Gas	RTC +R/C
^{30}Si	--	^{30}Si	--	H,S	Vac	
^{173,175}Os	7n	^{40}Ar	^{nat}Ce	H	He	C
$^{180-182}$Hg	2-4n	^{40}Ar	^{144}Sm	H,S	He	C
^{188}Pb	4n	^{48}Ca	^{144}Sm	H,S	He	
^{188}Pb	4n	^{40}Ar	^{152}Gd	H,S	He	
$^{194-196}$Pb	4-5n	^{40}Ar	^{nat}Gd	H,S	He	R
$^{198-199}$Bi	4-5n	^{22}Ne	^{181}Ta	H,S	He	catch
$^{195-196}$Po	4-5n	^{48}Ca	^{152}Gd,	H	He	R
^{200}At	3n	^{64}Ni	^{nat}La	TSp	He	
^{200}Fr	5n	^{64}Ni	^{141}Pr	TSp	He	
$^{205-206}$Fr	5-6n	^{30}Si	^{181}Ta	H	He	
$^{208-211}$Ra	3-4n	^{54}Cr	^{nat}Gd	H,S	He	
$^{208-211}$Ra	3-6n	^{64}Ni	^{150}Nd	TSp	He	
^{210}Ac	5n	^{40}Ar	^{nat}Lu	H,S	He,N_2	
^{215}Ac	4n	^{22}Ne	^{197}Au	H,S	He,H_2	
$^{218-x}$Th	xn	^{64}Ni	^{154}Sm	TSp	He	
$^{224-x}$U	xn	^{64}Ni	^{nat}Gd	TSp	He,H_2	
^{245}Fm	3n	^{40}Ar	^{208}Pb	H,S	He	R
^{252}No	2n	^{48}Ca	^{206}Pb	H,S, TSp	He	R
^{253}No	2n	^{48}Ca	^{207}Pb	H, TSp	He	
^{254}No	2n	^{48}Ca	^{208}Pb	H,S	He,H_2	
^{255}No	5n	^{22}Ne	^{238}U	H,S	He,H_2	R
^{256}No	4n	^{22}Ne	^{238}U	H	He	
^{260}Rf	6n	^{22}Ne	^{244}Pu	H	He,H_2	
^{261a,261b}Rf	5n	^{22}Ne	^{244}Pu	H	He	R,C
^{262}Rf	4n	^{22}Ne	^{244}Pu	H	He,H_2	

Extensive studies have been performed in the HTM and SIM to obtain optimized parameter sets for (i) the target thickness and stability, (ii) the gas pressure and the gas filling (He, H_2, and mixtures), (iii) the dipole setting (Bρ) and quadrupole focusing, (iv) the RTCs (window material and thickness, support structures, and size and shape of the chamber), (iv) gas-jet transport of pre-separated products, and (vi) the coupling and performance of devices

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like ROMA and the Automated Rapid Chemistry Apparatus (ARCA). Results of many of these parameter studies were compared with TASCA model calculations [7] and very good agreement was achieved. This agreement is of special importance as it allows for the selection of proper settings for magnetic rigidities (Bρ) in the dipole magnet and the quadrupole magnets for all nuclear reactions and for all gases and gas mixtures tested at various pressures. It is especially rewarding to see that not only Bρ values were properly chosen to centre product distributions on focal plane detectors (FPD) but also that the measured spatial distributions and, more importantly, the efficiencies were in very good agreement with model calculations. These results confidently demonstrate that we are able to perform trustworthy SHE experiments with TASCA. In the following, we mention a few concluding experiments, some of the highlights and new developments; see [2] for additional information on the parameter studies.

The first efficiency measurements with catcher foils behind the target and in the focal plane showed very good agreement with model calculations for the fairly asymmetric reaction ^{22}Ne(^{181}Ta,xn)^{198m,199}Bi [2]. To confirm this agreement in a more symmetric reaction, leading to a significantly heavier reaction product, and to obtain a standard reaction to test and check the TASCA performance, detailed studies were performed with well known reactions of ^{48}Ca with ≈ 0.5 mg/cm^2 thick targets of ^{206,207,208}Pb leading to ^{252,253,254}No. Assuming cross sections of 0.5 μb, 1.3 μb, and 2 μb [8] for the production of ^{252}No, ^{253}No, and ^{254}No, efficiencies of 54%, 56%, and 50%, respectively, were obtained for the HTM, using a He filling of 0.8 mbar, and a (80x36) mm^2 16-strip FPD. Taking into account uncertainties in cross sections and systematic errors of target thicknesses and beam current measurements, we observe an excellent agreement with model calculations [7] predicting 54%. Equally good is the agreement in the SIM, at a He pressure of 0.8 mbar, where a 30% efficiency was measured for the reaction ^{48}Ca(^{208}Pb,2n)^{254}No.

A new (140x40) mm^2 large, highly efficient FPD, consisting of double-sided silicon strip detectors (DSSSD) in the focal plane and SSSDs for the backward box detectors will further increase the TASCA efficiency; see [9] for details of the new detector.

As one of the crucial tests and one of the highlights finalizing the TASCA commissioning program, we studied the isotopes ^{260}Rf, ^{261a,261b}Rf, and ^{262}Rf synthesized in the very asymmetric reaction ^{22}Ne + ^{244}Pu; see [10] for details of the nuclear reactions, for TASCA parameters, and for the interesting nuclear decay results. In essence, the performance of TASCA was as anticipated; everything worked well, including the ^{244}Pu target wheel. Efficiencies and magnetic settings (Bρ=1.99 Tm at 0.4 mbar He, HTM) were as expected. As observed in previous experiments [2], it was again possible to reduce the background in the FPD by using a mixture of He and H_2. This part of the commissioning program showed clearly that TASCA can be applied efficiently for nuclear decay and nuclear reaction studies of neutron-rich nuclides of SHE synthesized in very asymmetric hot-fusion reactions. Rf isotopes were not only measured in the FPD but were also collected in an RTC and were transported either to ROMA for nuclear decay measurements [10] or to ARCA for chemical investigations [11].

An additional highlight of the experiment was the first transactinide chemistry behind TASCA designed as a proof-of-principle experiment. It was performed in ARCA with pre-separated 78-s ^{261a}Rf; details of the nuclear reaction and the Rf separation in TASCA are described in [10] while all chemical aspects are discussed in [11]. This successful experiment, which studied the formation of Rf-fluoride complexes and their adsorption behaviour on an anion-exchange resin, demonstrated that aqueous-phase transactinide chemistry behind TASCA can now be performed.

The new set-up termed *TA*sca *S*mall *I*mage mode *Spe*ctroscopy (TASISpec) [12] exploits advantages of the SIM, i.e. the fact that neutron-rich nuclides of SHE, produced in hot-fusion reactions, can be focused with high efficiency into an area of < 7 cm^2. This provides the unique possibility to build a compact Si-detector box for α-particle, electron, and fission-fragment measurements, and to pack composite Ge-detectors in very close geometry, resulting in an unprecedented, highly efficient set-up for multi-coincidence measurements with γ-rays and X-rays; see [12] for details. A prototype set-up has been commissioned successfully and first data have been collected for nuclides as heavy as ^{252,253}No.

In conclusion, the performance of TASCA as a separator is well understood and is perfectly under control. TASCA as a whole is presently the most versatile and highest efficient instrument in SHE research worldwide. It has entered the region of transactinides or superheavy elements, and is ready to explore the physics and chemistry of the "terra incognita" it was designed and built for.

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