First observation of new heavy multi-nucleon transfer products in the ^{48}Ca+^{248}Cm reaction performed at SHIP

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Introduction

Heavy ion fusion reactions have been successfully used to synthesise super heavy elements (SHE). The heaviest element produced up to now is element Z=118 and the production cross-section limit using conventional HI-fusion has been reached experimentally. Since these methods cannot be applied to reach neutron-rich super heavy nuclei due to the lack of sufficiently neutron-rich projectile and target nuclei. New calculations [1, 2] suggest the use of Multi Nucleon Transfer (MNT) reactions as a promising pathway to the synthesis of new neutron-rich SHE with proton numbers up to about Z = 106. In this work, we present results from the analysis of experimental data on MNT reactions with the ^{48}Ca projectile incident on ^{248}Cm target [3]. The experiment was performed at SHIP, GSI in 2010.

Experiment

The 270.2 MeV energy ^{48}Ca beam provided by the UNILAC accelerator with an average intensity of 2×10^{12} projectiles/s impinged on a 460 μg/cm^2 ^{248}Cm thick target. The target foils were mounted on a wheel rotating synchronously with the beam macro-pulsing of 5 ms (beam on) and 15 ms (beam off). The velocity filter SHIP has been adjusted to separate the deep-inelastic target-like reaction products with velocity 1.5-2.0 times the compound nucleus velocity (V_{CN}) from the primary beam and other reaction products.

After separation by the SHIP, the evaporation residues (ERs) were implanted into a 16-strip position-sensitive silicon detector (PSSD) with an active area of 80 × 35 mm^2 for measuring time, position and kinetic energy of the recoil as well as subsequent α-decays or spontaneous fission (SF). To measure the escaped alpha particle and fission products from the stop detector six silicon wafers, arranged like a box, were placed in front of the stop detector. They covered a solid angle of 85% of 2π.

Results and discussion

The data were analysed with a view to investigate the presence of possible transfer products produced through this reaction. The theoretical predictions [2] for MNT reactions indicate that for the system ^{48}Ca+^{248}Cm the production of heavy transuranium nuclei may also be achieved. The calculated average excitation energy for the primary target-like transfer products is around 40 to 60 MeV. The de-excitation takes place by emitting 4 to 6 neutrons, which shifts the isotopic distributions to the more neutron-deficient side. In this region most of the known isotopes are alpha emitters with short half-lives. This helps to identify the implanted decay products by following their decay chains.

A vast region of reaction products with proton numbers 84≤Z≤98 was identified through the α-decay chains. Fig. 1 shows the identified isotopes from the present work. It is clear from the figure that the identified isotopes reach out to the limit of the present Karlsruhe Chart of Nuclides of 2012 on the neutron-deficient side. We identified the new isotopes ^{216}U, ^{219}Np, ^{223}Am, ^{229}Am and ^{233}Bk for the first time [4]. The measured alpha decay energies and half-lives for these isotopes are listed in Table. 1. These findings indicate the first experimental proof of deep inelastic multi-nucleon transfer reactions as a means to the production of new heavy isotopes

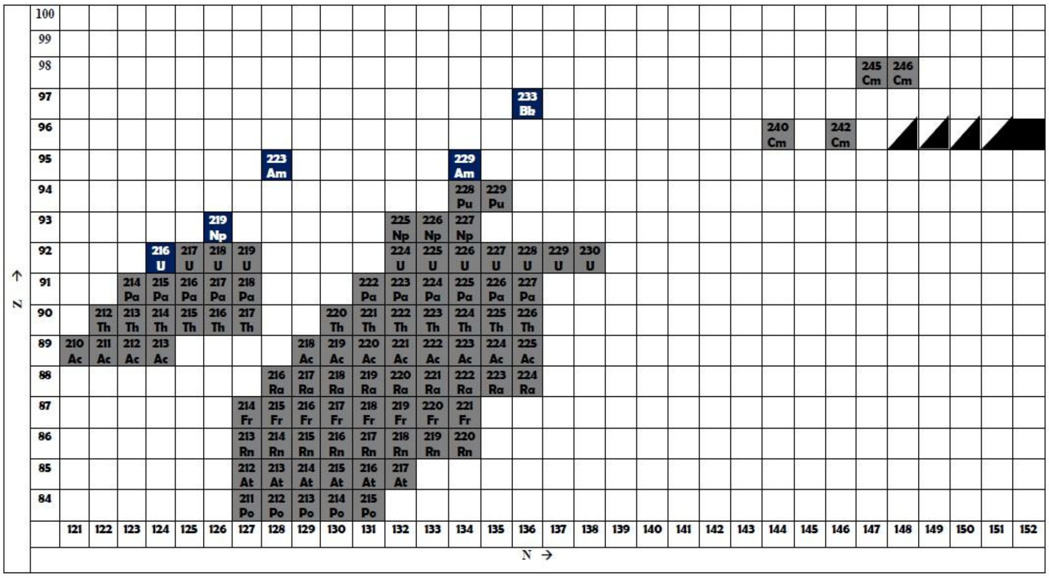

Fig: 1: Isotopes observed in collisions of ^{48}Ca+^{248}Cm. The new isotopes are indicated in white font color. The location of the ^{248}Cm target is shown by the black square. The target also contained small contributions (<3.2 %) from the isotopes $^{244\text{-}247}$Cm indicated by black triangles.

and possibly a viable way to reach the super heavies. Further investigations to understand and interpret these observations are underway.

Table. 1: Measured alpha energy and half-life of new isotopes.

Isotope	E_α (MeV)	$T_{1/2}$
^{216}U	8.34±0.05	$3.8^{+8.8}_{-3.2}$ ms
^{219}Np	>9.0	<5 µs
^{223}Am	17.4, pileup	$5.2^{+12.0}_{-4.4}$ ms
^{229}Am	7.99±0.02	$3.67^{+6.69}_{-1.45}$ s
^{233}Bk	7.77±0.02	$21.0^{+48.0}_{-7.0}$ s

These findings are submitted towards the partial fulfilment of a Ph.D. degree at MCNS, Manipal University by H. M. Devaraja.

This work is dedicated to the Late Valery Ivanovich Zagrebaev.

Acknowledgement:

This work has been carried out under the Manipal University-GSI-Giessen collaboration. One of the authors (H. M. D.) acknowledges financial support from the HIC for FAIR program.

References

1) V. Zagrebaev, W. Greiner, Nuclear Physics A **834**, 366 (2010).
2) V. Zagrebaev, W. Greiner, J. Phys. G: Nucl. Part. Phys. **35**, 125103 (2008).
3) S. Hofmann *et. al.*, Eur. Phys. J. A **48**, 62 (2012).
4) H. M. Devaraja *et. al.*, Physics Letters. B **748,** 199 (2015).