

TASCA 17

16th Workshop on

Recoil Separator for Superheavy Element Chemistry

September 01, 2017, GSI, Darmstadt, Germany

supported by the Helmholtz Institute Mainz

Location: KBW Auditorium

Program draft – 2017-08-18

TIME	TOPIC	Speaker	Page
09:00	Welcome	P. Giubellino/GSI	
	Accelerator developments	Chair:	
09:15	First HI beam acceleration with sc cw-Linac RF-structure at GSI	M. Miski-Oglu/HIM	2
09:40	NPI in Rez - New Site for Performing SHE-homologue Experiments	J.P. Omtvedt/ U. Oslo	2
10:05	Volatile carbonyl compounds for new radioactive ISOLDE ion beams	J. Ballof/CERN	3
10:30	Coffee		
	Physics highlights	Chair:	
10:50	Nuclear structure and quasifission dynamics	D. Hinde/ANU	4
11:15	Reaction studies to guide SHE synthesis in a post- ⁴⁸ Ca era	H. David/GSI	4
11:40	Nuclear No isotope properties from laser spectroscopy	S. Raeder/HIM	5
12:10	Workshop Photo		
12:25	Lunch		
	Facilities, technical developments	Chair:	
13:15	RITU and MARA, present status	J. Uusitalo/JYFL	5
13:40	Atomic-physics approach for determination of mean charges for heavy and superheavy ions in the dilute gases	V. Shevelko/LPI / HIM	6
14:05	Development, characterization and first applications of a Drop-on-Demand inkjet printing system for nuclear target fabrication	R. Haas/U.Mainz	7
14:30	Current Development State of Ion Exchanging alpha-Detectors	D. Krupp/HS Mannheim	6
14:55	Coffee		
	Chemistry	Chair:	
15:15	Recent Results on Theoretical Studies of Properties of SHE *	V. Pershina (GSI) / M. Ilias (Br./HIM)	7
15:50	Speeding up gas-phase chemistry to access elements beyond FI	S. Götz/HIM	8
16:15	Extraction of Nh homologs using "Designer" molecules	C.M. Folden III/TAMU	8
16:40	On-line studies with carbonyl complexes at TRIGA Mainz	M. Götz/HIM	9
17:05	Closing remarks		
17:10	End of TASCA 17 workshop		

All presentations include 20 minutes presentation plus 5 minutes discussion time except * (30 minutes presentation plus 5 minutes discussion time)

First acceleration of heavy ion beams with a superconducting cw-Linac RF-structure at GSI

M. Miski-Oglu

Helmholtz Institut Mainz, Germany

After successful RF-testing of a new superconducting Linac RF-cavity in 2016 and a short commissioning and ramp up time of some days, this Crossbar H-cavity, designed at Institute of Applied Physics of Goethe University Frankfurt, accelerated first time heavy ion beams with full transmission up to the design beam energy. For the first beam test the superconducting cavity was powered with 10 Watt of net RF power providing for an accelerating voltage of more than 1.6 Mega Volt inside a length of less than 70 cm. Meanwhile the design acceleration gain (3.5 Mega Volt) has been verified with heavy ion beam of up to 1.5 particle micro Ampere. The measured beam parameter, delivered by an Electron Cyclotron Resonance ion source and the GSI High Charge State Injector, show a nice beam quality – further and more detailed tests and careful evaluation of data are envisaged. The beam test is a milestone of the R&D work of Helmholtz Institute Mainz and GSI in collaboration with Goethe University Frankfurt in preparation of a superconducting heavy ion continuous wave linear accelerator. Further design and layout issues will be presented as well.

NPI in Rez - New Site for Performing SHE-homologue Experiments

Jon Petter Omtvedt¹, Jan John², Mojmír Němec², Jan Štursa³, Ondrej Lebeda³

¹ *University of Oslo, P.O. Box 1033 – Blindern, NO-0315 Oslo, Norway*

² *Czech Technical University, Břehová 7, CZ-115 19 Prague 1, Czech Republic*

³ *Nuclear Physics Institute, Czech Academy of Sciences, Rez, 250 68, Czech Republic*

The UiO SHE-group (headed by J.P. Omtvedt) used to successfully perform SHE-homologue experiments at the Oslo Cyclotron Laboratory (OCL). However the small Scanditronix SC35 cyclotron at OCL is not powerful enough to provide useful radionuclides for SHE-homologue studies except with ³He-particles. Unfortunately, the use of ³He-gas had to be abandoned after the drastic price increase during the recent years (the OCL gas-recycling was not efficient enough to keep the consumption reasonable).

Fortunately an opportunity for setting up the UiO target chamber and gas-transfer system became available at the U120M cyclotron at the Nuclear Physics Institute (NPI) in Rez (just outside Prague) in the Czech Republic. This enables similar homologue experiments as could previously be performed at OCL. At NPI a ³He²⁺ beam is available (like previously in Oslo), but with slightly higher energy (~50 MeV). Thus, we can produce homologues of the most relevant transactinides for test and development experiments with equal or better yields than we formerly could in Oslo. Initial test were performed in October 2016 that demonstrated that yields and production reactions worked as expected. NPI is planning to build a chemistry laboratory where experiments with gas-jet delivered SHE homologues can be performed – provided there is enough interest from the community. We have approval for performing experiments for the next three years. At the TASCA workshop we will present the results and capabilities of the NPI setup, together with the plans for the future.

As obtaining beam-time at the large machines (capable of producing SHEs) is frequently quite difficult we believe that the setup in Rez might be of interest to others than the UiO-CTU collaboration. We encourage inquiries about using the Rez setup and will use the TASCA workshop to point out this opportunity for the TASCA community.

Volatile carbonyl compounds for new radioactive ion beams at ISOLDE

^{1,2}J. Ballof, ¹C. Seiffert, ¹B. Crepieux, ¹J. P. Ramos, ¹S. Rothe, ¹T. Stora, ^{2,3,4}Ch. E. Düllmann, ^{3,4}A. Yakushev

¹CERN, Geneva, Switzerland, ²Univ. Mainz, Mainz, Germany; ³GSI, Darmstadt, Germany
⁴HIM, Mainz, Germany

The ISOLDE facility at CERN allows the production of high intensity radioactive ion beams by the use of thick targets within the ISOL (isotope separation on-line) process. Thick targets are bombarded by high energy protons (1.4 GeV), supplied by the proton synchrotron booster. The nuclear reaction products diffuse out of the target container and into the ion source, where they are typically ionized in hot cavities, by electron bombardment, plasmas or by resonant laser ionization.

Despite the manifold new developments introduced to ISOL target units within the last 60 years, the beam extraction of elements with very high boiling points (refractory elements) remains a very challenging topic. Due to their vanishingly low volatility, radionuclides of these elements generated by the driver beam are captured within the target and suffer from hampered release. [1]

Increased target temperatures enhance the diffusion processes and decrease the sticking times on surfaces, but the maximum temperature of a target unit is limiting the capabilities of this approach. The most promising way to extract beams of refractory elements is the in-situ formation of volatile molecules. A reactive gas can therefore be introduced through a calibrated leak inside the target container. The products of the nuclear reaction undergo the chemical reaction inside the target container, which will then effuse to the ion source.

While the extraction of molecular sidebands is exploited since many years, its application to the most refractory elements was so far of limited success. However, following new developments, which came up in the field of super heavy element chemistry within the last years [2], a new compound class might open up new perspectives for the extraction of the most refractory elements. Highly volatile carbonyl complexes $M(\text{CO})_x$, $x=5-6$ of suitable elements were found to form already at ambient temperature and pressure upon thermalizing fission fragments in a carbon monoxide containing atmosphere. The ISOLDE Periodic Table of Elements shown in Figure 1 demonstrates the potential of the “carbonyl method”. Nine out of fifteen transition metals, which are not yet available as beam, form volatile carbonyl compounds.

1																	2
H																	He
3	4											5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne
11	12											13	14	15	16	17	18
Na	Mg											Al	Si	P	S	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	La...	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

Figure 1 - Periodic Table of elements showing available beams at ISOLDE (green / dark grey), Non-available Elements, which form transition metal carbonyls (red background / light grey) and carbonyl chalcogenides (red frame).

While carbonyl compounds have proven to be suitable means of transportation, they are delicate compounds. Decomposition on hot surfaces, by electron beams, in plasmas and upon exposure to UV-light is expected, which provides new challenges for the ionization of the compound. This is especially the case for typical ISOLDE radioactive beam ion sources which are operated between 1500 and 2200 °C. Within this work, different types of ion sources were systematically investigated with respect to their applicability for carbonyl complex ionization. To account for the thermal fragility, a FEBIAD type ion source was modified to allow the injection of carbonyl complexes along a colder path directly into the anode body of the source. In addition, two

RF driven cold plasma sources were tested and the laser-induced break-up of carbonyl complexes as essential preparatory step to resonant laser ionization was also experimentally addressed.

Moreover, simulations aiming at the production of radioisotopes, stopping of fission recoils in a gas atmosphere and simulations for the cryogenic separation of carbonyl complexes were conducted. As next steps, we plan on-line experiments to investigate the carbonyl-based beam production at ISOLDE as well as further ionization tests with a mono charge ECR ion source.

References

- [1] U. Köster et al., (Im-)possible ISOL beams, Eur. Phys. J. Special Topics 150, 285-291 (2007).
- [2] J. Even et al., In-situ formation, thermal decomposition, and adsorption studies of transition metal carbonyl complexes with short-lived radioisotopes, Radiochimica Acta 102, 1093-1110 (2014).

Nuclear structure and quasifission dynamics

David Hinde

Australian National University, Canberra

To obtain a better understanding of the quasifission process, that inhibits superheavy element formation, extensive measurements of quasifission mass-angle distributions have been carried out at the Australian National University. Projectiles of ^{48}Ca , ^{50}Ti , ^{54}Cr , ^{58}Fe and ^{64}Ni bombarded targets of ^{249}Cf , ^{248}Cm , ^{244}Pu , ^{238}U , ^{232}Th and ^{208}Pb . Beam energies from below-barrier to above-barrier have been measured. With an enhanced detector setup allowing c.m. angular coverage from 20 to 160 degrees, these new mass and angle data reveal the difference in the typical reaction timescale, and the associated mass evolution dynamics in these reactions. This new information is complementary to previous fission mass-energy distribution measurements. It throws light on the difference between cold fusion and hot fusion reaction dynamics, but also raises questions that will need further investigation.

Reaction studies to guide the pathway to superheavy synthesis in a post- ^{48}Ca era

H.M. David¹ and J. Khuyagbaatar^{1,2}

on behalf of the GSI/HIM/ANU/JGU collaboration

¹*GSI, Darmstadt, Germany*

²*Helmholtz Institut Mainz, Germany*

Synthesising superheavy elements (SHE) in the laboratory presents a great number of challenges, and rapidly reducing cross sections with increasing Z result in the requirement for up to months-long experimental campaigns in order to observe a single atom. Nevertheless, the heaviest elements with $Z=114-118$ have been successfully produced. This has been achieved using fusion-evaporation reactions with ^{48}Ca beams on actinide targets. However, a lack of sufficient target material past Cf prevents the use of ^{48}Ca as a projectile to synthesise elements beyond Og ($Z=118$), necessitating the use of heavier projectiles.

Despite several searches for elements beyond Og using the $^{64}\text{Ni} + ^{238}\text{U}$, $^{58}\text{Fe} + ^{244}\text{Pu}$, $^{54}\text{Cr} + ^{248}\text{Cm}$, $^{50}\text{Ti} + ^{249}\text{Cf}$ and $^{50}\text{Ti} + ^{249}\text{Bk}$ reactions, no SHE observations have been reported. Whereas SHE formation can occur when the binary system undergoes complete fusion reaching a compact nuclear shape, the competing quasifission process, where the dinuclear system rapidly reseparates before a compound nucleus forms, dominates and thus severely hinders SHE synthesis.

As we move into an era where ^{48}Ca -induced reactions are no longer viable for synthesis of new elements, a comprehensive experimental campaign has been carried out at the Heavy Ion Accelerator Facility at the Australian National University to investigate entrance-channel effects on the formation of nuclei with $Z=120$. An upgraded CUBE detector was used to measure fission fragments originating from $^{64}\text{Ni} + ^{238}\text{U}$, $^{58}\text{Fe} + ^{244}\text{Pu}$, $^{54}\text{Cr} + ^{248}\text{Cm}$ and $^{50}\text{Ti} + ^{249}\text{Cf}$ reactions, as well as from $^{48}\text{Ca} + \text{actinide}$ reactions. Preliminary results of these studies will be presented here.

Inferring nuclear properties of nobelium isotopes by laser spectroscopy

S. Raeder*^{1,2}

for the RADRIS collaboration

¹*Helmholtz-Institut Mainz, 55128, Mainz, Germany;*

²*GSI Darmstadt, Planckstraße 1, 64291 Darmstadt, Germany;*

**s.raeder@gsi.de*

Laser spectroscopy allows precisely measuring atomic properties of an element to map its electronic structure. This is of particular importance for the heaviest elements where the electron shell is strongly influenced by electron-electron correlation and relativity. These effects change the electron shell configuration and thus the chemical behavior [1,2]. By resolving subtle changes in the center position and the structure of an optical resonance, laser spectroscopy furthermore enables to infer information on the deformation and the intrinsic moments of the atomic nucleus.

The study of nuclear properties for nobelium (No, Z=102) isotopes became possible after the first identification of a strong $^1S_0 \rightarrow ^1P_1$ ground state transition in pioneering experiments at GSI, Darmstadt, where a sensitive technique based on two-step resonance ionization was applied [3,4]. Nobelium ions were produced in the fusion-evaporation reaction with a ^{48}Ca primary beam impinging on a lead target. They were separated from the primary beam by the velocity filter SHIP, stopped in high-purity argon gas and collected onto a thin tantalum filament. After re-evaporation the neutral atoms were probed by two-step resonance ionization and the created photo-ions were detected by their characteristic alpha decay. Here, the isotope shifts of the ground-state transition were measured for the isotopes $^{252-254}\text{No}$ as well as the hyperfine splitting in ^{253}No . In combination with atomic calculations, we determined the evolution of the deformation of the nobelium isotopes in the vicinity of the deformed shell closure at neutron number N=152 and extracted the magnetic moment and the spectroscopic quadrupole moment of ^{253}No . These results will be discussed and the prospects for extending laser spectroscopy to heavier elements and towards high-resolution laser spectroscopy of nobelium isotopes and isomers will be given

References

- [1] E. Eliav, S. Fritzsche, U. Kaldor, Nucl. Phys. A 944, 518 (2015).
- [2] P. Schwerdtfeger, L. F. Pašteka, A. Punnett, P. O. Bowman, Nucl. Phys. A 944, 492 (2015).
- [3] H. Backe, W. Lauth, M. Block, M. Laatiaoui, Nucl. Phys. A 944, 492 (2015).
- [4] M. Laatiaoui, W. Lauth, H. Backe, M. Block, et al., Nature 538, 495-498 (2016).

RITU and MARA, present status

Juha Uusitalo

for the Nuclear Spectroscopy Group

University of Jyväskylä, JYFLACCLAB

An extensive JUROGAM campaign was performed using the gas-filled recoil separator RITU. Now this campaign is finished and the JUROGAM detectors are sent to France (Orsay) for about one year. In one-year time a rail system for in-beam Ge-arrays between RITU and MARA target position will be built. During fall 2018 MARA should be ready for an in-beam RDT-campaign to be started. While RITU was in heavy use a commissioning campaign was performed with the newly MARA. MARA was tested with different kind of kinematics. In these tests, it was demonstrated that MARA works as ion-optics suggests. Also one experiment, originally planned for RITU, using ^{78}Kr beam on ^{92}Mo and ^{96}Ru targets was performed. In this experiment two new isotopes, namely ^{169}Au and ^{165}Pt , was identified using correlation techniques. In this work the present status of JYFLACCLAB in-flight separators RITU and MARA will be presented.

Atomic-physics approach for determination of mean charges for heavy and superheavy ions in the dilute gases

J. Khuyagbaatar¹ and V.P. Shevelko²

¹ *HIM, Mainz and GSI, Darmstadt, Germany*

² *P.N. Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia and HIM Fellow, Mainz, Germany 01.06-31.10.*

An atomic-physics approach for determination of equilibrium and non-equilibrium charge-state fractions as well as the mean charges for heavy and superheavy elements in the dilute gases is discussed. The approach is based on solving the balance rate equations for charge-state fractions with coefficients equal to electron-loss and electron-capture cross sections [1]. Two main effects, playing a key role in such calculations, are discussed: the influence of multiple-electron processes and the target-density (gas-solid) effect. The properties of a newly created BREIT code [2] are discussed. The results of atomic calculations for equilibrium, non-equilibrium charge-state fractions and the mean charges are compared with available experimental data observed at gas-filled recoil separator TASCA.

References

- [1] J. Khuyagbaatar, V.P. Shevelko et al., Phys. Rev. A 88 042703 (2013).
- [2] N. Winckler, A. Rybalchenko, V.P. Shevelko et al., NIM. B 392, 67 (2017).

Current Development State of Ion Exchanging α -Detectors

D. Krupp, U. W. Scherer

*HS Mannheim – Institute of Physical Chemistry and Radiochemistry
Paul-Wittsack-Str. 10, 68163 Mannheim/D*

Organosilanes are used to change the physical and chemical properties of oxidic structures, without causing changes in deeper layers of the substrate [1,2]. Once a bifunctional silane is anchored to an oxidic structure, functional groups can be introduced to investigate physical, chemical or biological properties of a sample [3].

If an alpha detector is modified by such a synthesis strategy, many radiochemical experiments, especially in the field of super heavy elements become accessible by aqueous chemistry where conventional preparation and subsequent alpha spectrometry would be too slow for investigations of short lived isotopes.

In this work, the current development state of a chemical selective detector is discussed. As a proof of principle surface implanted Si-detectors were modified with cation exchange groups. Uranyl cations were adsorbed by sulfonic acid groups within 30 seconds. Afterwards the detector surface was extensively flushed with water and mounted in a vacuum chamber. ^{238/234}U-Spectra were obtained with FWHM of around 70 keV. After the measurement the uranyl cations were completely desorbed by flushing the detector surfaces with small quantities of concentrated hydrochloric acid.

In addition, the measurements were simulated in the alpha-simulation program AASI [4].

These AASI models are used to predict the thickness of the depleted silane layers. Moreover, these simulations are used for planning more complex radiochemical experiments in flowcells, equipped with chemically selective detectors..

References

- [1] D. K. Aswal et al., Analytica chimica acta, 2006, 568, 84 - 108.
- [2] S. Onclin et al., Angew. Chem. Int. Ed., 2005, 44, 6282–6304.
- [3] M. B. Ali et al., Materials Science and Engineering: C, 2008, 28, 628–632.
- [4] AASI – Program for simulating energy spectra in alpha spectrometry. www.stuk.fi

Development, characterization and first applications of a Drop-on-Demand inkjet printing system for nuclear target fabrication

R. Haas¹, Ch. E. Düllmann^{1,2,3}, K. Eberhardt¹, S. Lohse¹, C. Mokry¹, J. Runke²

¹*Univ. Mainz, Germany*

²*GSI, Darmstadt, Germany*

³*Helmholtz Institut Mainz, Germany*

A novel target preparation method based on Drop-on-Demand (DoD) inkjet printing has been developed and characterized. Conventional preparation methods like the electrochemical method "Molecular Plating" [1, 2] or the "Polymer-Assisted Deposition Method" [3, 4] are often limited, e.g., concerning the dimensions and geometries of depositions or by the requirement for electrically conducting substrates. An alternative method includes manual pipetting on superhydrophobic surfaces, which overcomes the problem with ring-shaped deposits but suffers from position inaccuracy [5]. An automated pipetting system has recently been built by a group at the Paul Scherrer Institute (PSI), Villigen, Switzerland, to overcome the limits in accuracy of manual pipetting and has been used for the production of targets for experiments of the n_tof collaboration at CERN [6]. The application of precision printing systems like DoD inkjet printing has recently spread increasingly in many branches of the natural sciences. Here, we report on the development of such a DoD printing system for nuclear target fabrication, which overcomes above limits by using a commercially available DoD dispenser. A variety of solutions with volumes down to 5 nL can be dispensed onto every manageable substrate. The dispensed volumes were determined with radioactive tracers and the deposits of evaporated salt solutions were investigated on titanium and graphene foils. Additionally, the high precision of the printing system where individual drops can be positioned was used to determine the spatial resolution of storage phosphor imaging plates with three tracers of different β -decay energies [7]. The new technique is able to produce new kinds of targets with improved spatial geometries and thin layer deposits.

References

- [1] W. Parker, R. Falk, Nucl. Instr. Meth. Phys. Res. A 16 (1962) 355-357.
- [2] A. Vascon et al., Nucl. Instr. Meth. Phys. Res. A 696 (2012) 180-191.
- [3] M. A. Garcia et al., Thin Solid Films 516 (2008) 6261-6265.
- [4] M. A. Garcia et al., Nucl. Instr. Meth. Phys. Res. A 613 (2010) 396-400.
- [5] D. Renisch et al., Nucl. Instr. Meth. Phys. Res. A 676 (2012) 84-89.
- [6] E. A. Mauger et al., J. Instr. 12 (2017) P02016.
- [7] R. Haas et al., submitted to Nucl. Instr. Meth. Phys. Res. A (2017).

Recent Results on Theoretical Studies of Properties of Superheavy Elements

V. Pershina¹ and M. Ilias²

¹*GSI, Darmstadt, Germany*

²*HIM, Mainz, Germany & Matej Bel University, Banská Bystrica, Slovakia*

To render assistance to experiments on adsorption of Cn, Nh and Fl on gold and quartz, the theoretical research has recently been focusing on predictions of interaction of all these elements and their lighter homologs with a silicon oxide and gold surfaces. The calculations were performed for the first time using a periodic relativistic code, the ADF BAND. It allows for modelling adsorption processes on extended systems, i.e., on real surfaces of solids.

We have also calculated electronic structures and properties, including the first bond dissociation energies of group-6 and 8 carbonyls including those of Sg and Hs. Principally new results than earlier reported have been obtained for Sg(CO)₆. Trends in the groups have been established and relativistic effects influence has been elucidated.

Speeding up gas-phase chemistry to access elements beyond Fl

S. Götz^{1,2,3}, M. Block^{1,2,3}, Ch.E. Düllmann^{1,2,3}, C. M. Folden III⁵, K. J. Glennon⁵, M. Götz^{1,2,3}, E. Jäger², O. Kaleja^{2,4}, J. Krier², L. Lens^{1,2,3}, A.K. Mistry^{1,2}, S. Raeder^{1,2}, E. E. Tereshatov⁵, M. F. Volia⁵, A. Yakushev^{1,2}

¹ Helmholtz Institut Mainz, Germany

² GSI, Darmstadt, Germany

³ Univ. Mainz, Germany

⁴ TU Darmstadt, Germany

⁵ Cyclotron Institute, Texas A&M University, College Station, TX, USA

In recent years, the chemical properties of the SuperHeavy Elements (SHE) copernicium (Cn, Z = 112) and flerovium (Fl, Z = 114) have been extensively studied. Here, the combination of the gas chromatography with the electromagnetic preseparator TASCA was an indispensable tool to obtain the required sensitivity for the single-atom studies. Gas chromatographic techniques, which rely purely on flowing gas to flush the produced isotopes into the chromatography detector column, were implemented. This approach is applicable to isotopes with half-lives that are not less than 0.5 seconds because of comparable subsecond extraction time of recoils under such conditions. Looking at elements beyond Fl, everyone can note that the half-lives of the most long-lived isotopes are significantly shorter. For moscovium (Mc, Z = 115), for example, the most long-lived currently known isotope is ²⁸⁸Mc with $T_{1/2} = 170 \left(\begin{smallmatrix} +40 \\ -30 \end{smallmatrix} \right)$ ms. To get access to such short-lived isotopes, a faster extraction technique is accordingly needed. This talk covers the combination of a gas stop cell with electric fields and the COMPACT detector. This new gas-catcher allows extraction times in the range of tens of milliseconds.

In order to extend such studies, the efficiency, extraction time and sensitivity of the gas-stop-cell-COMPACT setup is being further optimized. In this contribution, the development of the gas stop cell and of a new COMPACT-design will be discussed. An overview of the offline (GSI) and online (Texas A&M University) results will be given.

Extraction of Nh Homologs Using “Designer” Molecules

Charles M. Folden III

Cyclotron Institute, Texas A&M University, College Station, TX 77843-3366 USA

In recent years, one focus of heavy element research at Texas A&M University has been studying the use of modern “designer” molecules for their potential application in superheavy element chemistry experiments. These have included ionic liquids (organic salts that are liquid at room temperature) [1, 2], deep eutectic solvents (DESs) [3], and low-transition-temperature materials [3]. These materials allow are tunable in their size, hydrophobicity, and other properties, which allows for fine control of metal extraction from an aqueous phase to an organic phase. In recent years, our group has studied the extraction of the expected Nh homologs In and Tl using these extractants. We have also begun similar experiments utilizing zwitterionic betainium-based ionic liquids, which allow for additional levels of tunability. This talk will summarize the most recent results on these experiments and give an overview of the capabilities available at Texas A&M for offline and online experiments.

References

- [1] E. E. Tereshatov et al., J. Phys. Chem. B 120, 2311 (2016).
doi:10.1021/acs.jpcc.5b08924
- [2] E. E. Tereshatov, M. Yu. Boltoeva, and C. M. Folden III, Solvent Extr. Ion Exc. 33, 607 (2015).
doi:10.1080/07366299.2015.1080529
- [3] E. E. Tereshatov, M. Yu. Boltoeva, and C. M. Folden III, Green Chem. 18, 4616 (2016).
doi:10.1039/C5GC03080C

On-line studies with carbonyl complexes at TRIGA Mainz

M. Götz^{1,2,3}, Ch.E. Düllmann^{2,3,1}, A. Yakushev^{3,1}, M. Asai⁴, J. Ballof⁵, A. Di Nitto^{2,3}, K. Eberhardt^{2,1}, S. Götz^{1,2,3}, H. Haba⁶, E. Jäger³, Y. Kaneya⁴, Y. Komori⁶, J.-V. Kratz², J. Krier³, B. Lommel³, A. Mitsukai⁴, Y. Nagame⁴, T. Sato⁴, A. Toyoshima⁴, K. Tsukada⁴, V. Wolter², V. Yakusheva³

¹HIM, Mainz, ²Univ. Mainz, ³GSI, Darmstadt, ⁴JAEA, Tokai, ⁵CERN, ⁶RIKEN

The chemical investigation of the superheavy elements is of broad interest, as relativistic effects, which scale with Z^2 , are predicted to strongly influence the chemical behavior of these elements [1]. Thus, trends in the periodic table might be broken. Comparative studies of the transactinides with their lighter homologs help to understand the influence of relativity on the electron shell and test the predictive power of the periodic table. Currently the method of choice for the synthesis of transactinides and their related carbonyl complexes is the combination of physical preseparation with carbonyl chemistry, whereby efficiencies are limited by a relatively large angular spread for asymmetric heavy-ion reactions as needed for the carbonyl studies with Sg, Bh, and Hs. Thus the transmission efficiency through an on-line recoil separator is relatively low. In case of TASCA or GARIS [2], the efficiencies are in the order of 10% for Sg. In case for the synthesis of the lighter homologs of the heavy transactinides, the TRIGA Mainz is an excellent tool for the relatively simple and easily accessible synthesis of radionuclides from lighter transition metals such as Mo. Thus, experiments were performed at the TRIGA Mainz Reactor, whereby short-lived radioisotopes, produced in neutron-induced fission of ^{235}U , were thermalized in a gas-filled chamber behind the target. This target chamber was continuously flushed with nitrogen. Directly at the exit of this target chamber, a chemical reaction chamber was installed, into which carbon monoxide gas was injected which thus bypassed the recoil chamber. Volatile reaction products were transported with the gas stream, trapped on a charcoal filter and the decaying isotopes were identified by their γ -lines. Scientific main goal was to distinguish and optimize the transport efficiency for volatile carbonyl complexes of non-volatile radioisotopes between the recoil- and the reaction chamber. Previous experiments [3] with an ^{235}U -Target and offline measurements, performed with a ^{248}Cm spontaneous fission source, revealed promising transport efficiencies up to 40% and thus, the new two-chamber approach looks to be a promising alternative to the application of physical preseparation. Further experiments should be performed at the TRIGA Mainz to investigate the influence of gas purification on the carbonyl synthesis, as well as the influence of different carrier gases.

References

- [1] P. Pyykkö, J.P. Desclaux. *Acc. Chem. Res.* 12, 276–281 (1979).
- [2] H. Haba et al. *Phys. Rev. C* 85, 24611 (2012).
- [3] V. Wolter. Master thesis, University of Mainz, Institute for Nuclear Chemistry (2016).