

Status on the chemical investigations of Fl at TASCA

Lotte Lens^{1,2} for the TASCA Flerovium Chemistry Collaboration

¹Johannes Gutenberg University Mainz, Germany

²GSI Darmstadt, Germany

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L.Lens@gsi.de



LUNDS
UNIVERSITET



UNLV




The TASCA Flerovium Chemistry Collaboration

GSI Darmstadt (D)	A. Yakushev, M. Block, H. Brand, H. David, F.P. Heßberger, J. Hoffmann, A. Hübner, E. Jäger, B. Kindler, J. Krier, N. Kurz, B. Lommel, V. Pershina, J. Runke, M. Schädel, B. Schausten, J. Steiner
Univ. Mainz (D)	Ch.E. Düllmann, A. Di Nitto, K. Eberhardt, J.V. Kratz, <u>L. Lens</u> , C. Mokry, P. Thörle-Pospiech, N. Trautmann, N. Wiehl
HIM Mainz (D)	M. Götz, S. Götz, J. Khuyagbaatar, M. Laatiaoui, A. K. Mistry, P. Scharrer, V. Yakusheva
Univ. Liverpool (UK)	R.-D. Herzberg, L. Harkness-Brennan, D. Judson, A. Ward
Univ. Lund (S)	U. Forsberg, P. Golubev, D. Rudolph, L. Sarmiento
Univ. Jyväskylä (F)	J. Konki, P. Papadakis, J. Uusitalo
Univ. Oslo (N)	J.P. Omtvedt
RIKEN, Wako-shi (J)	H. Haba, Y. Komori
JAEA, Tokai (J)	M. Asai, Y. Nagame, T. Sato, K. Tsukada
IITR Uttarakhand, (IN)	M. Maiti
SINP Kolkata (IN)	S. Lahiri
LLNL Livermore, (USA)	J. Despotopulos, K. Moody, D. Shaughnessy
ANU Canberra, (AU)	D. Hinde, E. Williams
ITE Warsaw (PL)	M. Wegrzecki

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- ❖ Experimental electronic department GSI

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- ❖ JAEA ASRC's Reimei Program
- ❖ ENSAR Travel support Program

Introduction

The image shows a periodic table of elements. The elements 112 (Cn), 114 (Fl), and 118 (Og) are highlighted in green and circled in red. The element 14 (Si) is also highlighted in green. The periodic table is arranged in rows and columns, with atomic numbers and element symbols visible.

1																	18	
H											B	C	N	O	F	Ne		
Li	Be											Al	Si	P	S	Cl	Ar	
Na	Mg	3	4	5	6	7	8	9	10	11	12	Ga	Ge	As	Se	Br	Kr	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	In	Sn	Sb	Te	I	Xe	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	Hg	Tl	Pb	Bi	Po	At	Rn
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Cn	113	Fl	115	Lv	117	118	
Fr	Ra	Ac+	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	112	113	114	115	116	117	118	

Are elements 112, 114, and 118 relatively inert gases?

Kenneth S. Pitzer

*Department of Chemistry and Inorganic Materials Research Division of the Lawrence Berkeley Laboratory,
University of California, Berkeley, California 94720*

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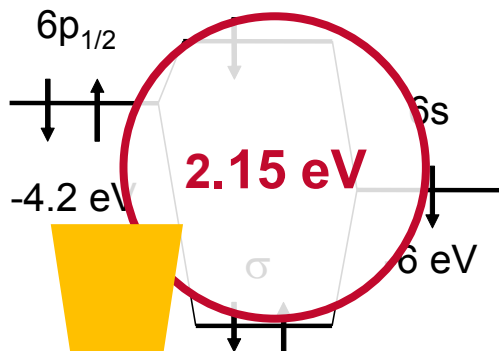
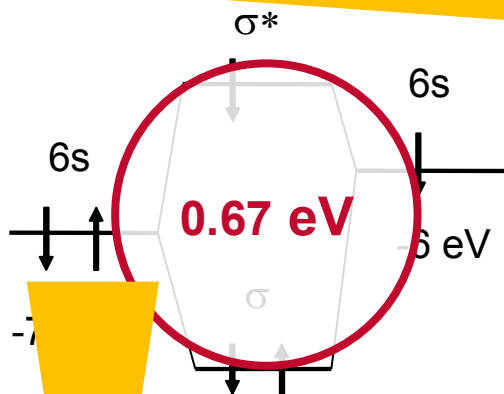
M-Au Bonding (Dimer)

Group 12

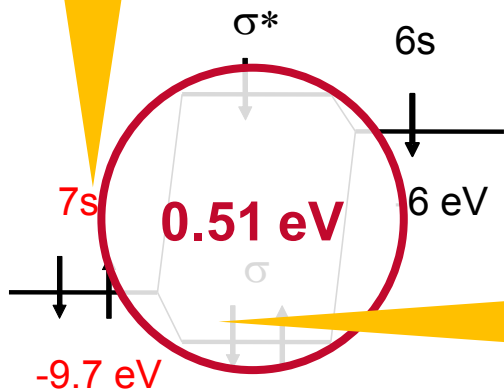
Hg-Au

Group 14

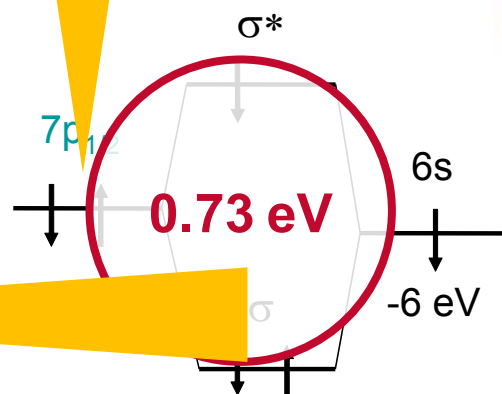
Pb-Au



Cn-Au

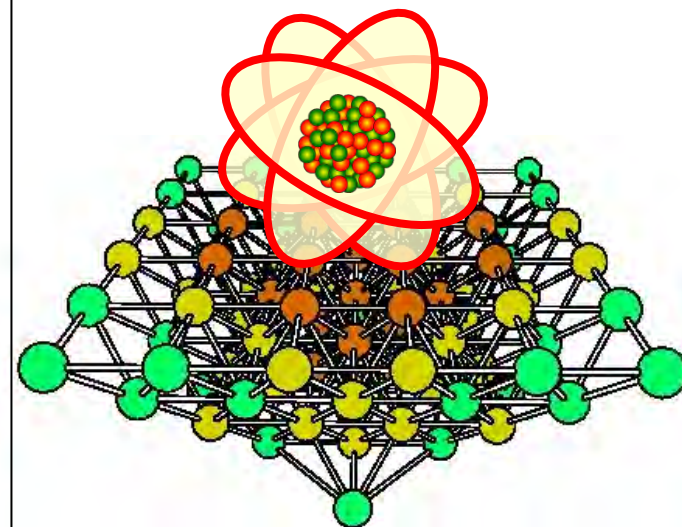


Fl-Au



Fl-Au bond is stronger than Cn-Au

M on Au_n cluster












Trend from M-Au to M-Au_n is preserved!

[V. Pershina]



Calculations for Cn-Au_n and Fl-Au_n

Binding energies (in eV) of Cn-Au_n and Fl-Au_n for Au(100) and Au(111)

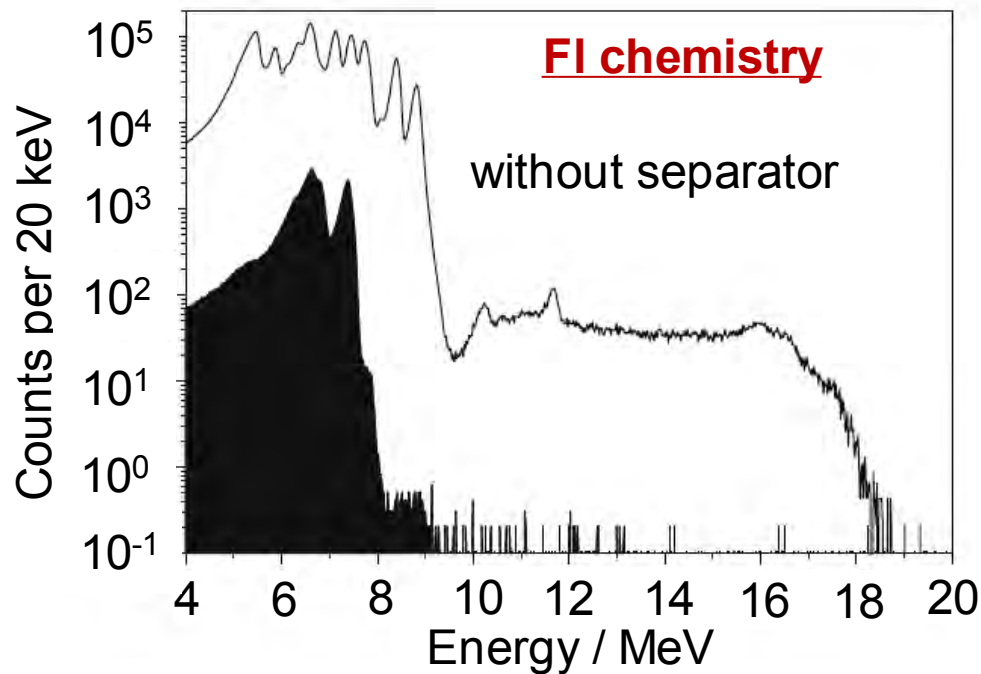
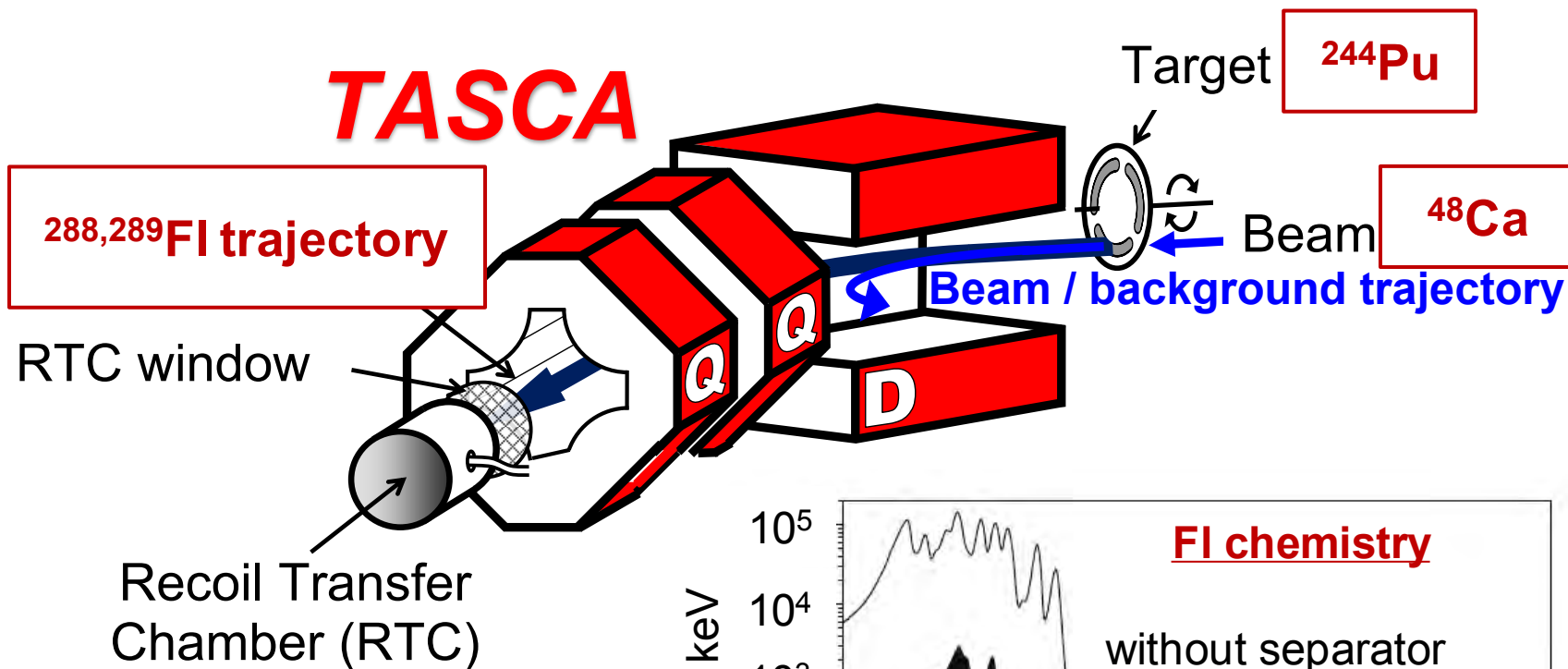
Method	n	Cn-Au _n	Fl-Au _n	Ref.
4c-DFT (B88/P86)	1	0.51 	0.73	1
2c-DFT (B88/P86)	1	0.47 	0.72	2,3
SO-DFT (B88/PW91)	3	0.47 	0.77	2,3
RPP+2c-DFT (B88/P86)	26 (bridge) Au(100)	0.33 	0.55	4
4c-BLYP	1 Au(111)	0.44 	0.70	3
4c-BP86	1 Au(111)	0.52 	0.77	3
4c-DFT (B88/P86)	95 (hollow) Au(111)	0.30 	0.47	1
-"-	94 (bridge) Au(111)	0.42 	0.71	1
-"-	107 (hollow2) Au(111)	0.46 	0.59	1

1. V. Pershina *et al.* J. Chem. Phys. 131, 084713 (2009)
2. E.A. Rykova *et al.* J. Chem. Phys. 125, 241102 (2006)
3. S. Rampino *et al.* J. Chem. Phys. 143, 024307 (2015)
4. A. Zaitsevskii *et al.* Russ. Chem. Rev. 78, 1173 (2009)

[V. Pershina, TAN2011, Sochi, Sept. 5-11 (2011)]



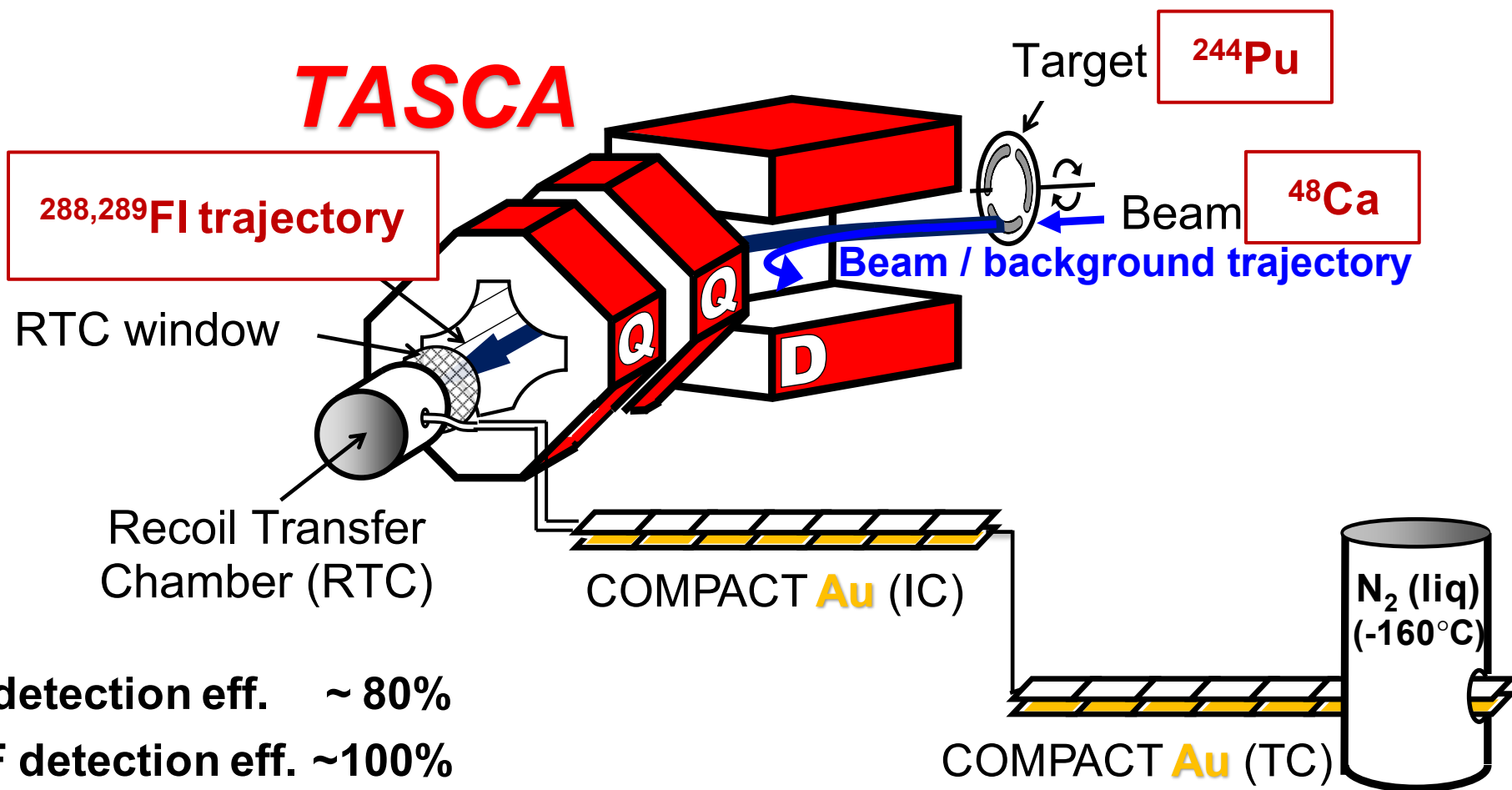
Experimental setup



[A. Yakushev, *et al.* Inorg. Chem. 53, 1624-1629 (2014)]

[D. Wittwer *et al.*, NIM B 268 (2010) 28–35]

Experimental setup



- ❖ α detection eff. $\sim 80\%$
- ❖ SF detection eff. $\sim 100\%$
- ❖ Full digital electronics

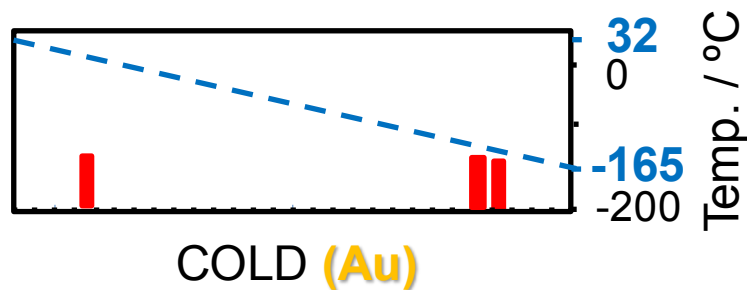
[N. Kurz *et al.*, GSI Scientific Report 252 (2012)]

[J. Hoffmann *et al.*, GSI Scientific Report 253 (2012)]

[J. Khuyagbaatar *et al.*, GSI Scientific Report 212 (2012)]

Experimental status

2007 (PSI / FLNR) (without separator, 5 weeks, beam dose: $6 \cdot 10^{18}$)

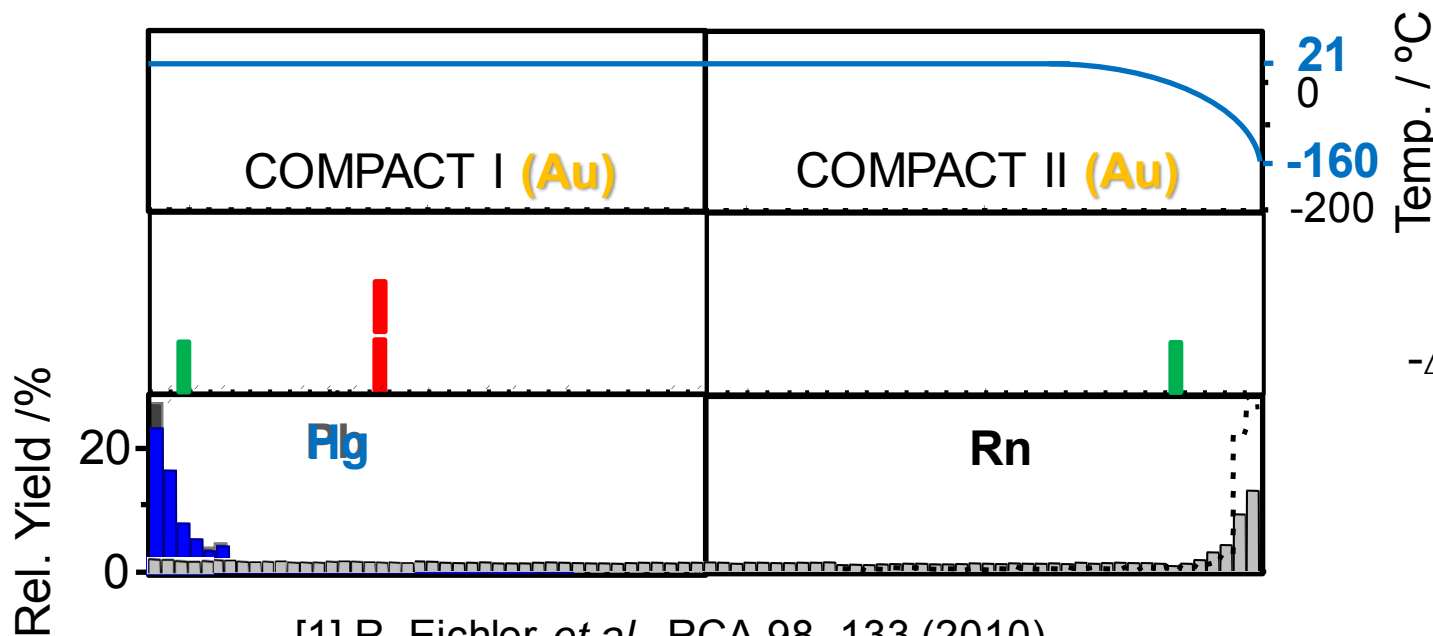


$$-\Delta H_{\text{ads}}^{\text{Au}(\text{FI})} = 34^{+54}_{-11} \text{ kJ/mol}^{[1]}$$

➤ Weak physisorption bond FI(Au)

2009 GSI Darmstadt (with separator, 4 weeks, beam dose: $4 \cdot 10^{18}$)

■ FI decay ■ SF



$$-\Delta H_{\text{ads}}^{\text{Au}(\text{FI})} > 48 \text{ kJ/mol}^{[2]}$$

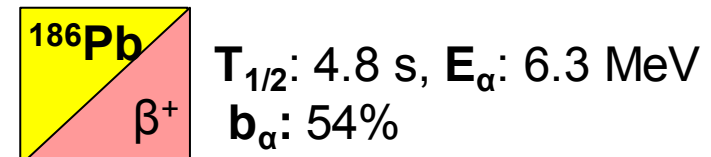
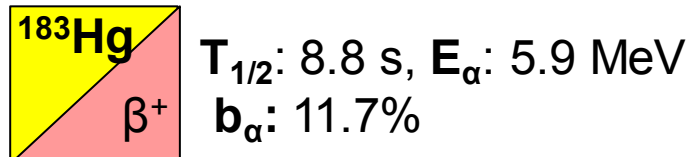
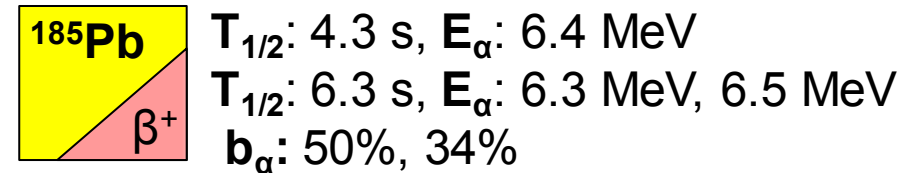
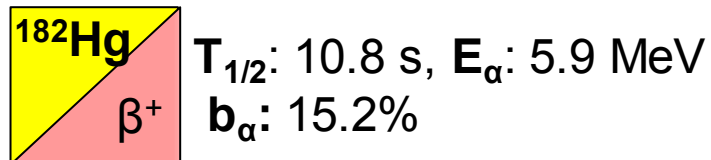
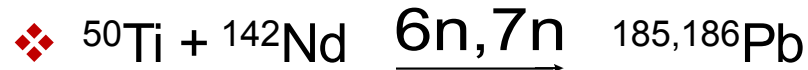
➤ Metallic character

[1] R. Eichler *et al.*, RCA 98, 133 (2010),

[2] A. Yakushev *et al.*, Inorg. Chem. 53, 1624 (2014)

Results of preparatory experiments with Pb and Hg

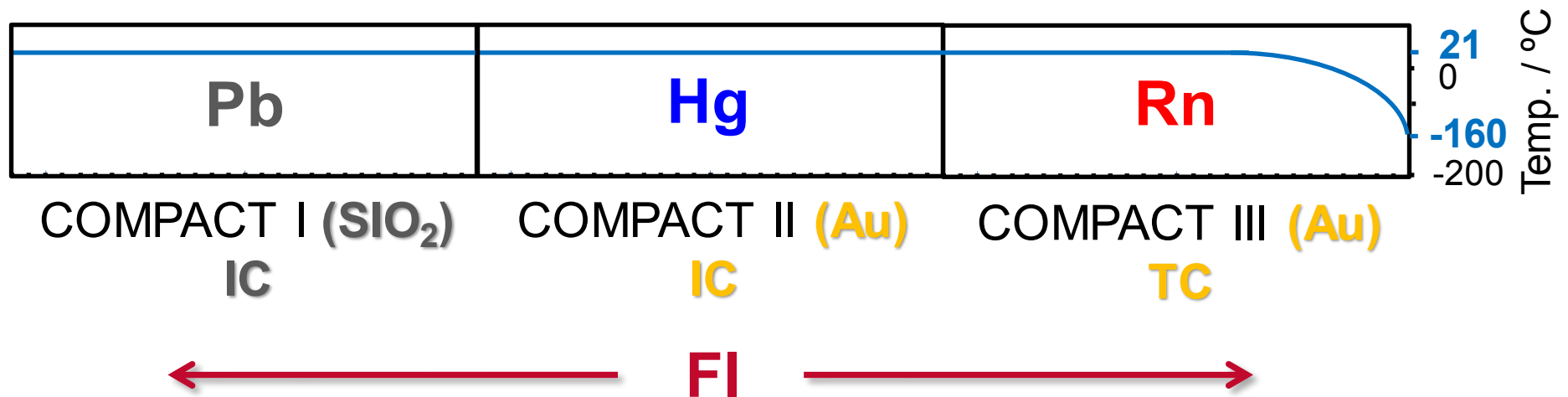
Reaction



FI experiment at TASCA 2014

Scope:

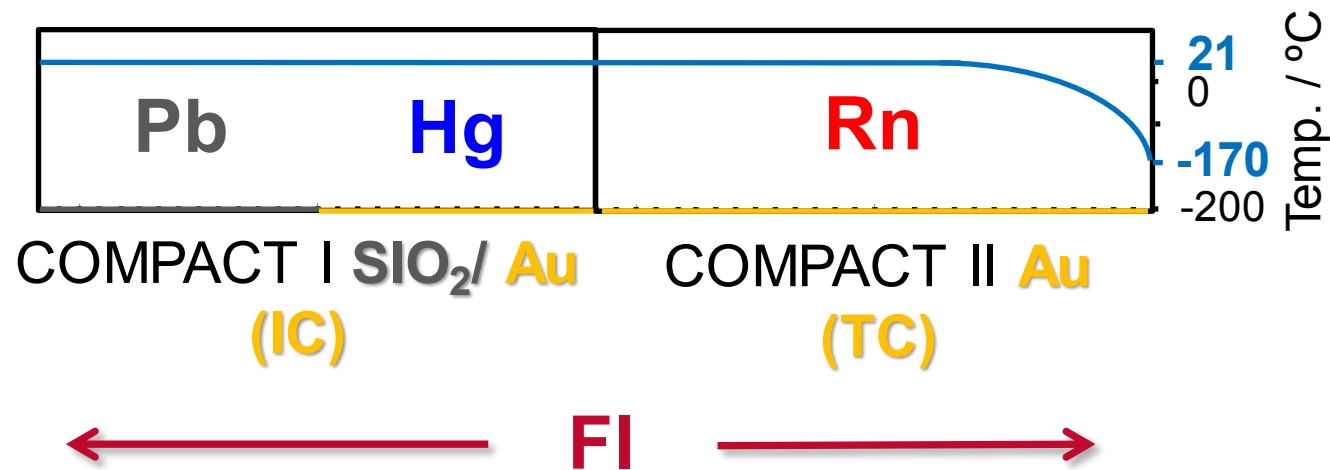
- ❖ Experimental investigations on the chemical properties of $^{288,289}\text{Fl}$ in comparison to Pb, Hg, Rn and Cn



The Flerovium Experiment 2015

Scope:

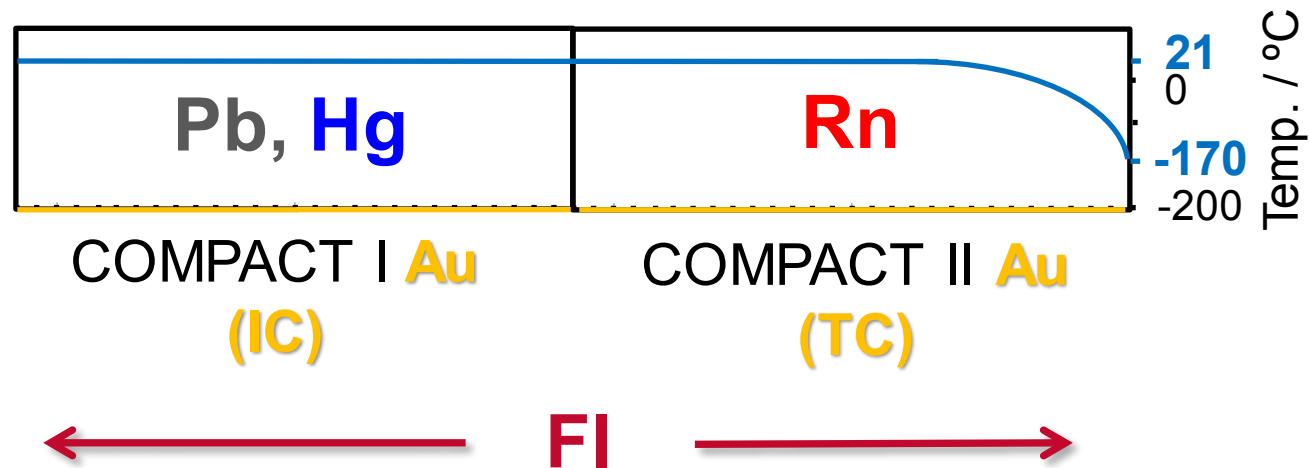
- ❖ Optimization of the transport time with Hg
- ❖ Experimental investigations on the chemical properties of $^{288,289}\text{Fl}$ in comparison to Pb, Hg, Rn and Cn



The Flerovium Experiment 2015

Scope:

- ❖ Optimization of the transport time with Hg
- ❖ Experimental investigations on the chemical properties of $^{288,289}\text{Fl}$ in comparison to Pb, Hg, Rn and Cn



Flerovium experiments 2014 + 2015

Data are currently being analyzed