First foot prints of chemistry on the shore of The Island of SHE

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for a collaboration of

with

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LLNL Livermore

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FZD Rossendorf

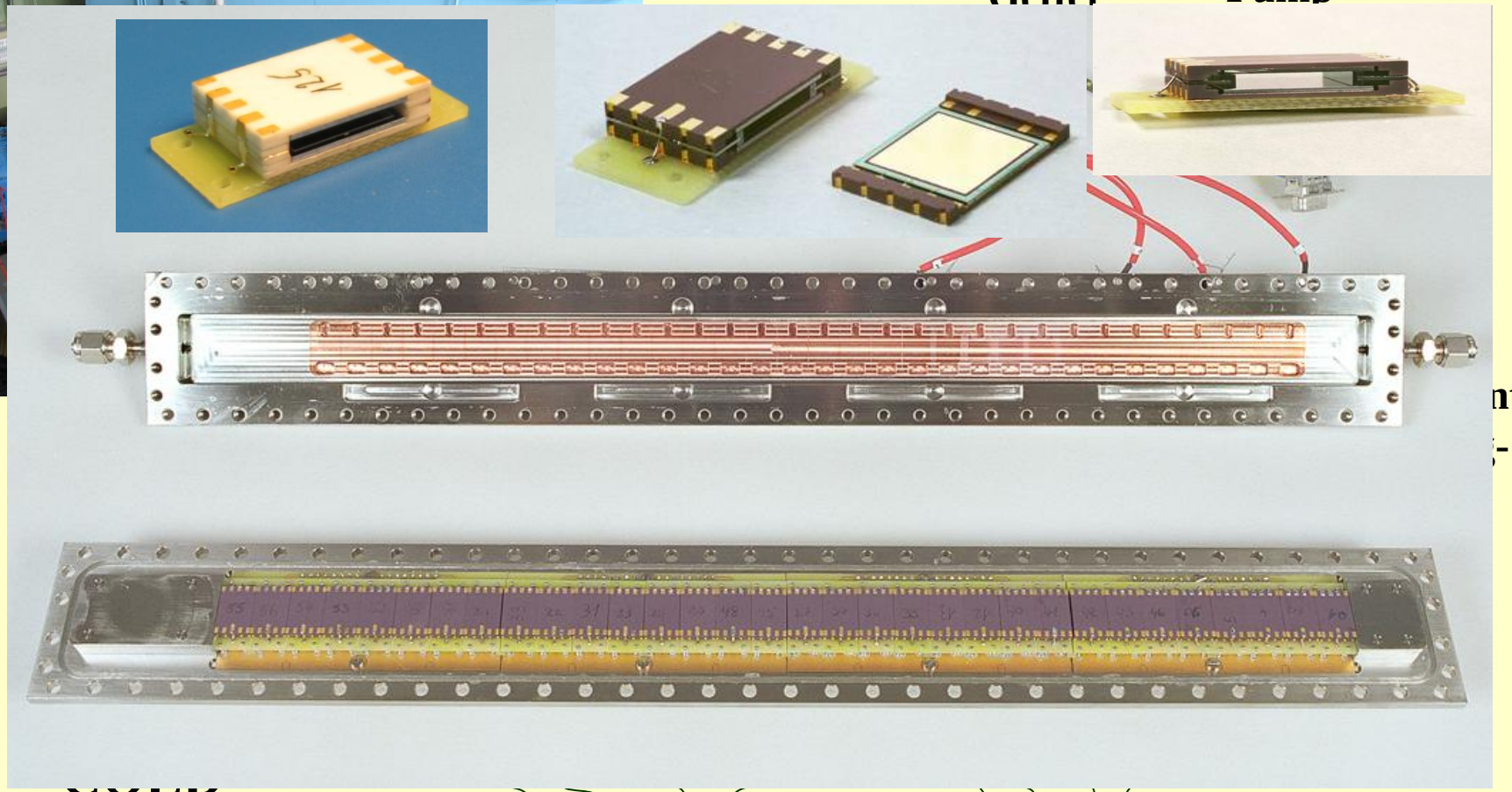
M.Wegrzecki
ITE Warzaw

Chemistry of Transactinides

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	113	114	115	116	117	118

*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Thermochromatography of SHE



Hg (α)

Rn (α)

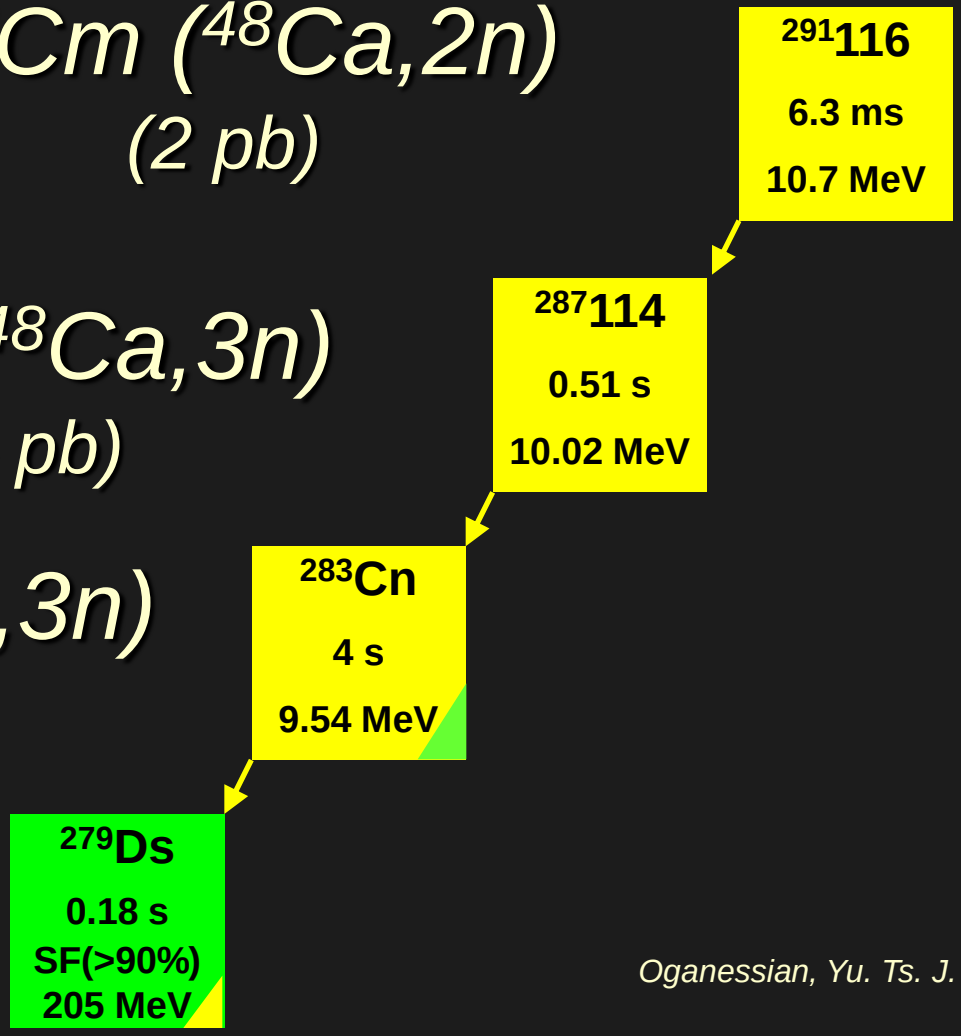
Model experiments! *S. Soverna et al. Radiochim. Acta 2005*

The Observation @ FLNR 1999-2004

$^{248}Cm\ (^{48}Ca,2n)$
(2 pb)

$^{242}Pu(^{48}Ca,3n)$
(4 pb)

$^{238}U(^{48}Ca,3n)$
(1 pb)



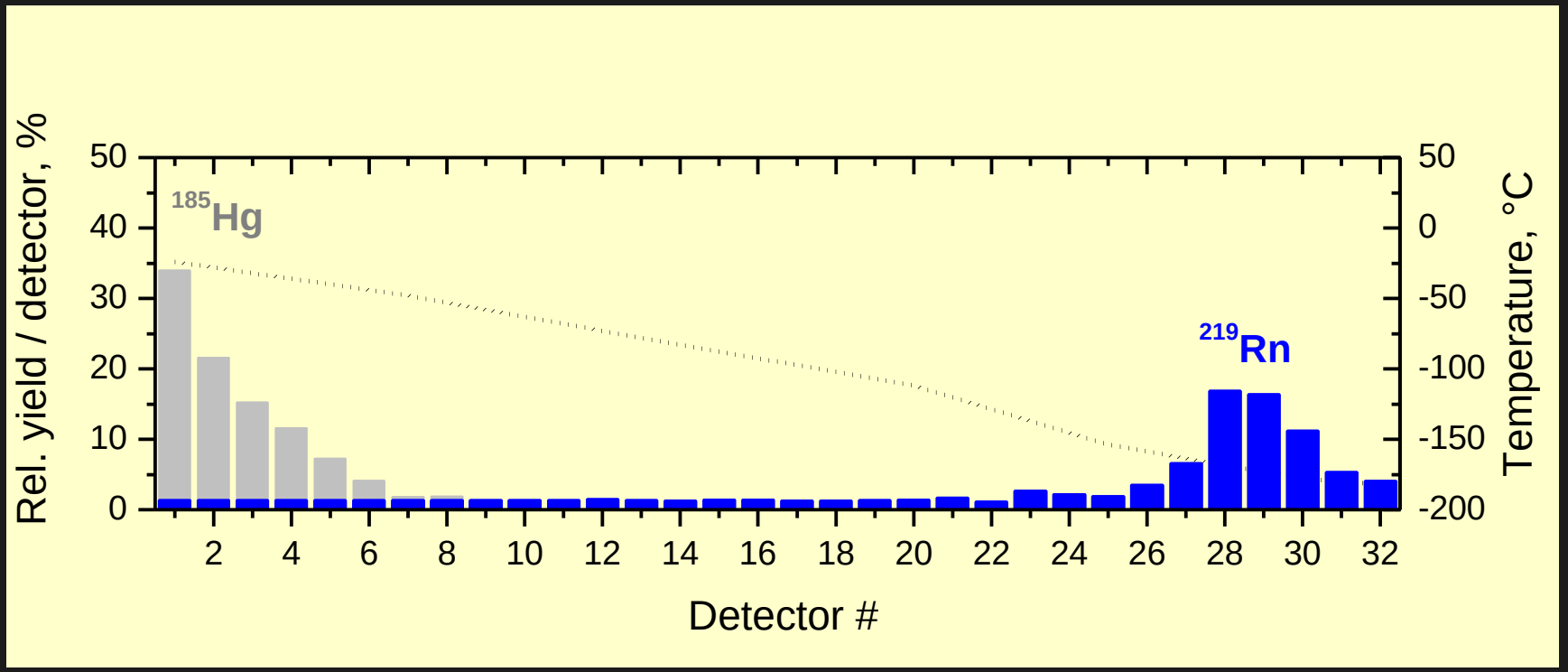
Oganessian, Yu. Ts. J. Phys. G 34, R165 (2007).

Hg and Rn

Deposition of ^{185}Hg and ^{219}Rn along COLD

^{142}Nd(^{48}Ca,5n)^{185}Hg
admixture ^{nat}Nd (50μg/cm^2)

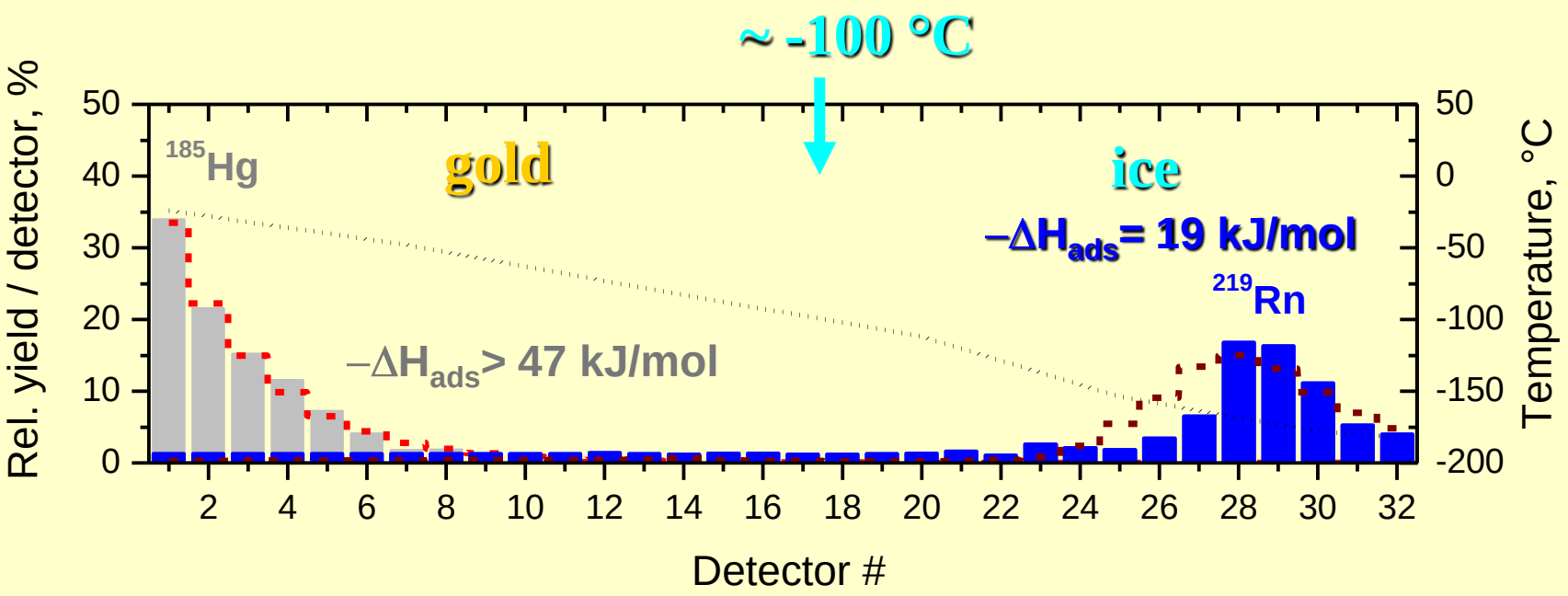
From multinucleon transfer reactions

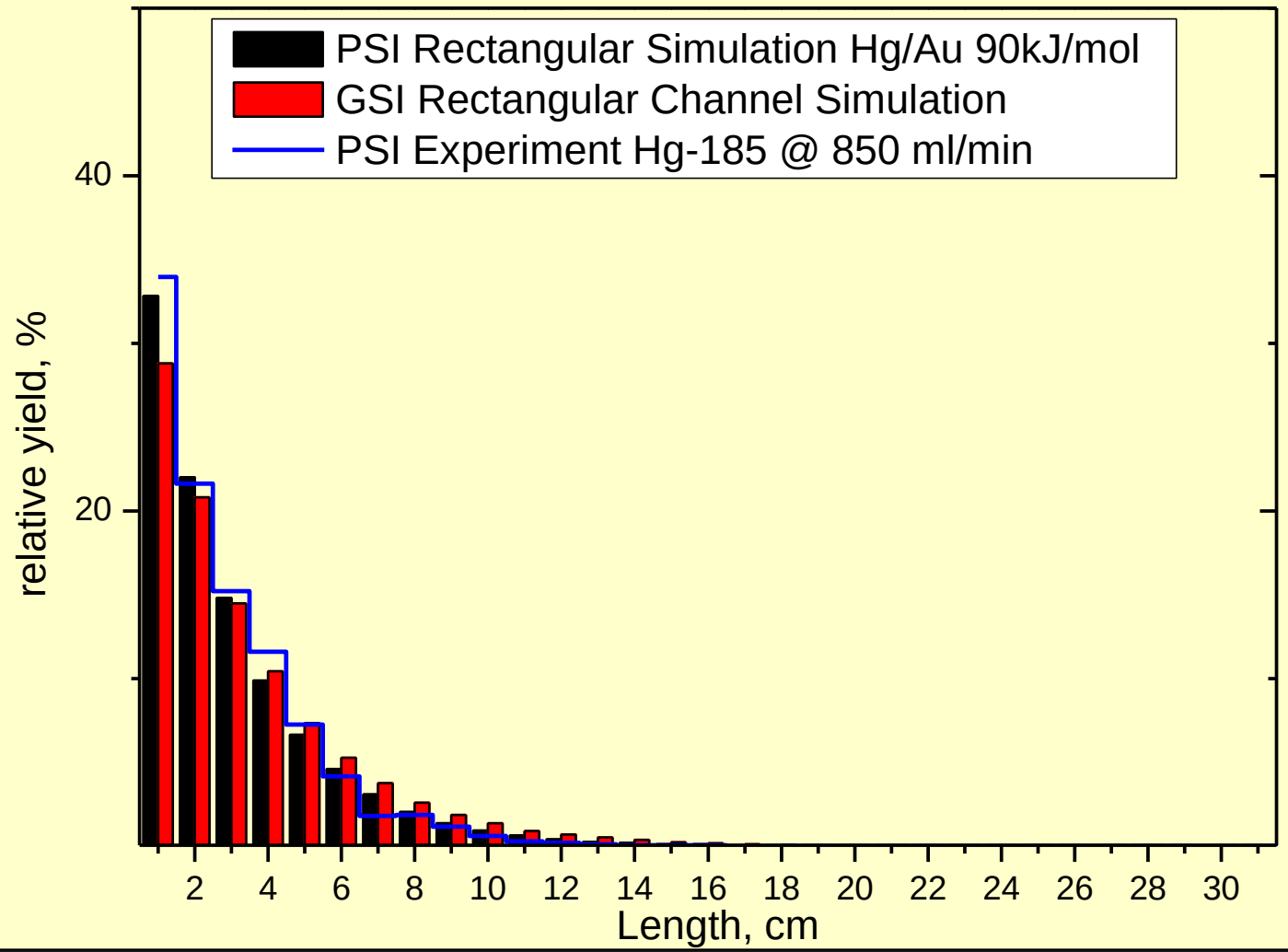


Hg and Rn ?

Deposition of ^{185}Hg and ^{219}Rn along COLD

Monte Carlo Simulations of TC




Temperature Gradient from 24-->-182°C
PSI Rectangular Simulation Hg/Au 90kJ/mol
GSI Rectangular Channel Simulation
PSI Experiment Hg-185 @ 850 ml/min
relative yield, %
40
20
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Length, cm

The Observation @ FLNR 2006/2007

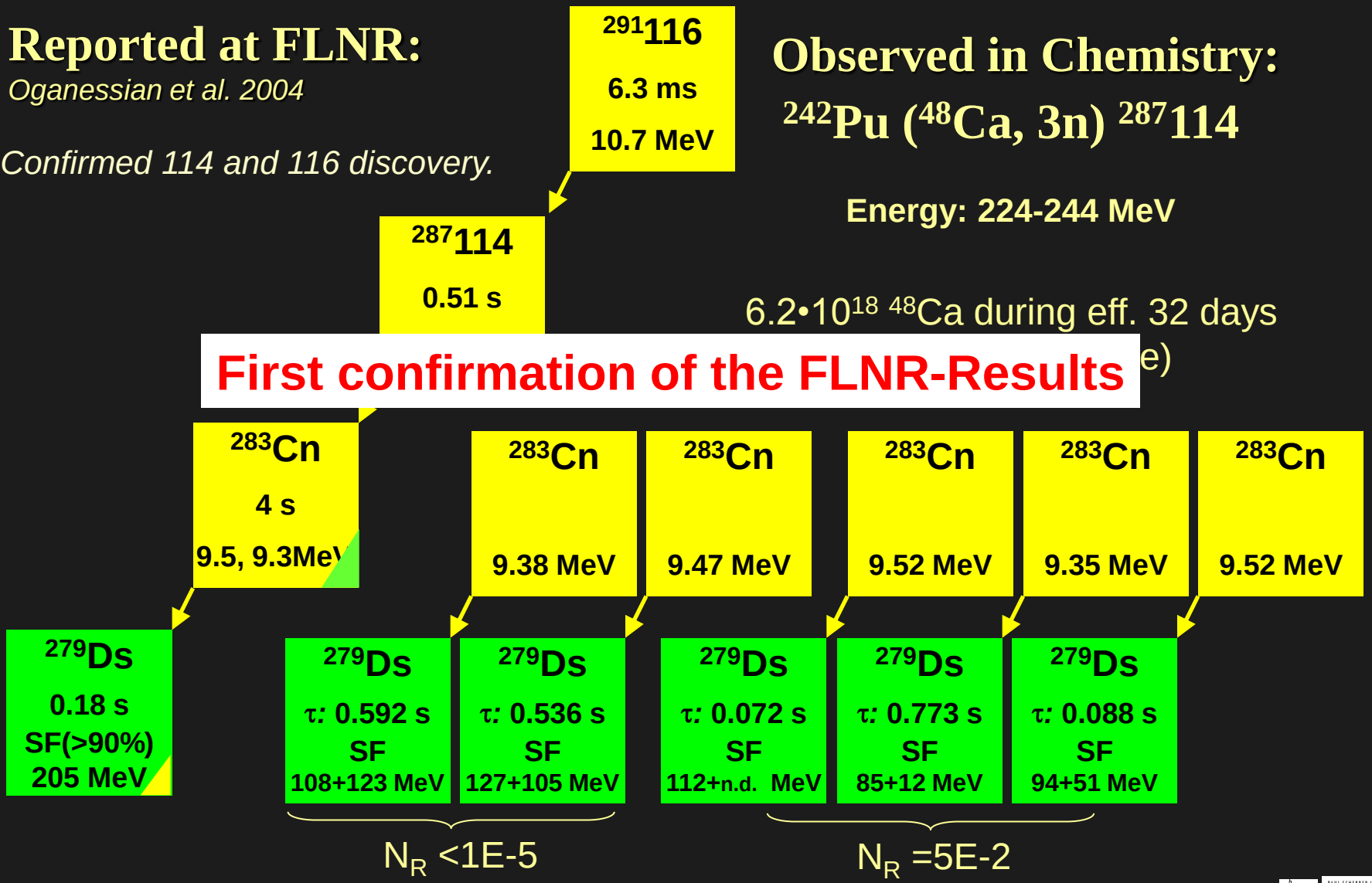
Reported at FLNR:
Oganessian et al. 2004

Confirmed 114 and 116 discovery.

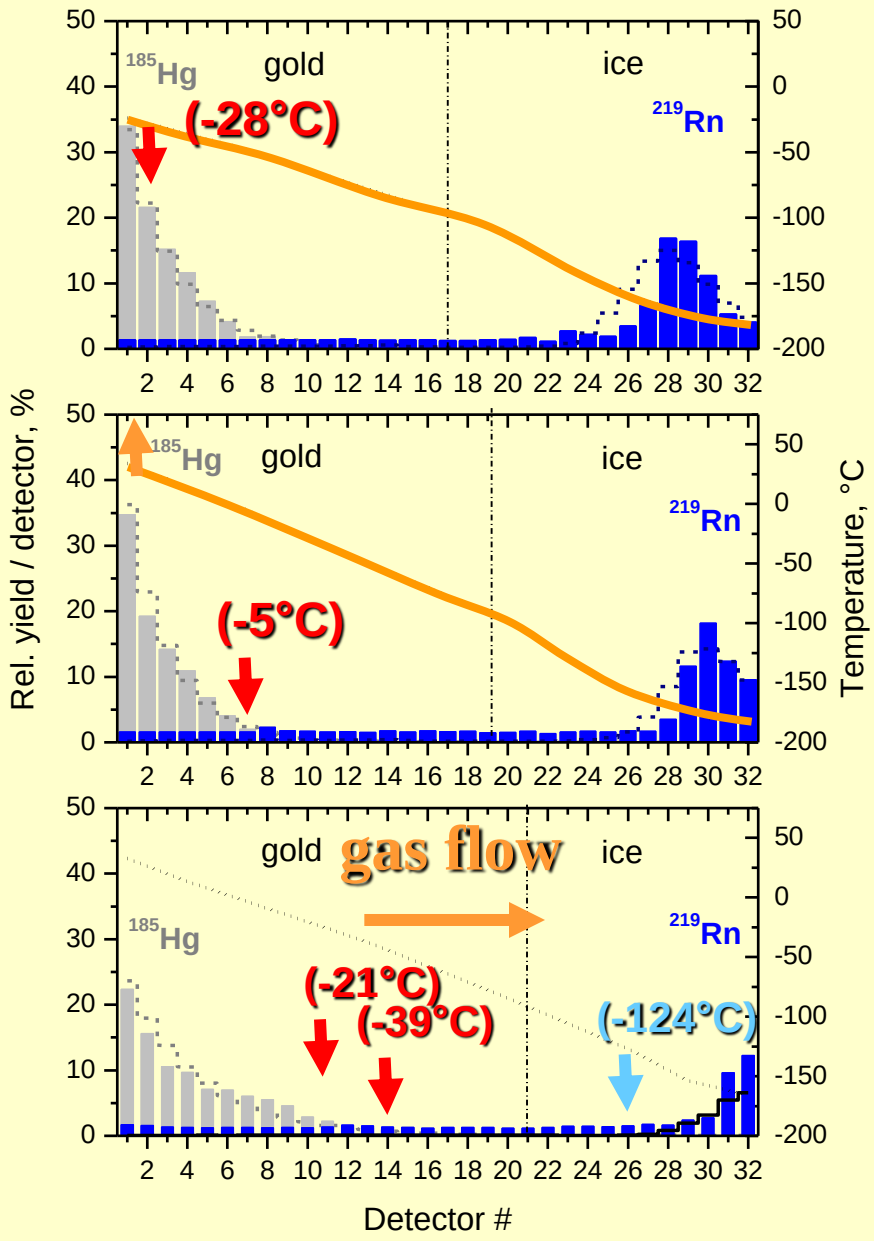
Observed in Chemistry:
^{242}Pu (^{48}Ca, 3n) ^{287}114

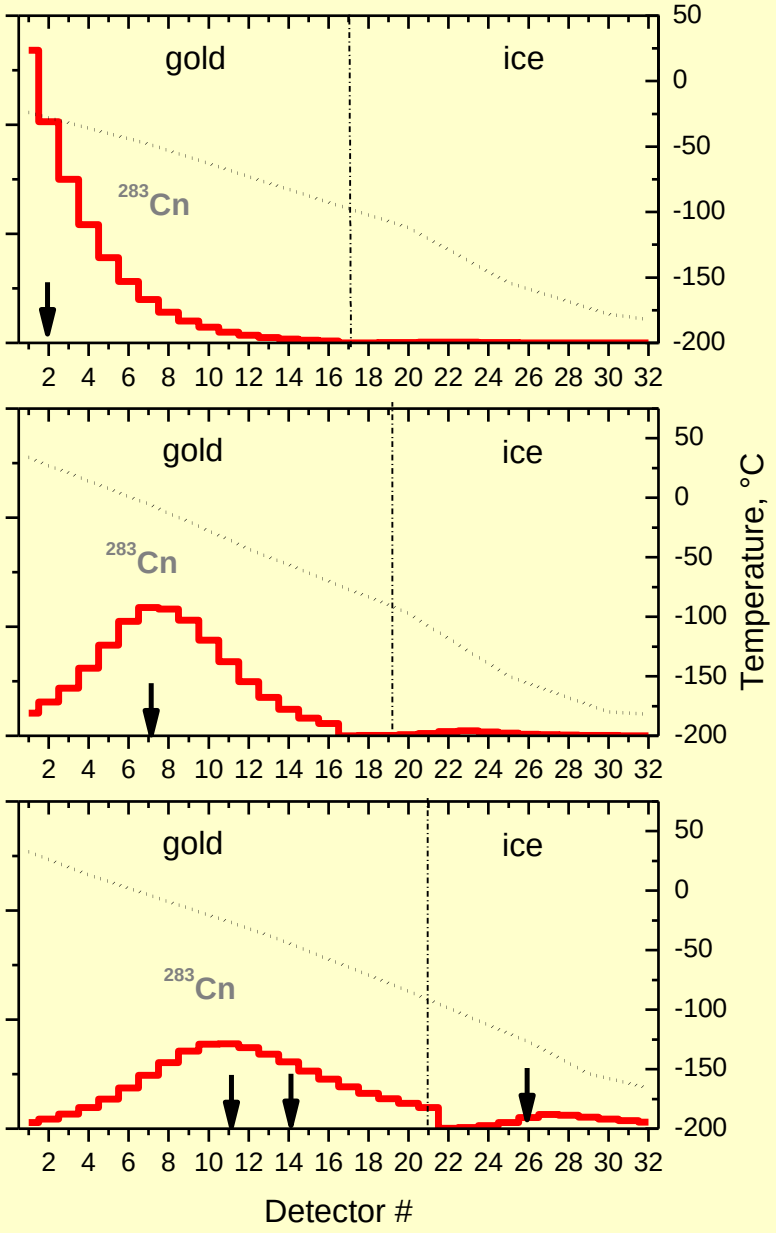
Energy: 224-244 MeV

6.2•10^{18} ^{48}Ca during eff. 32 days
e)

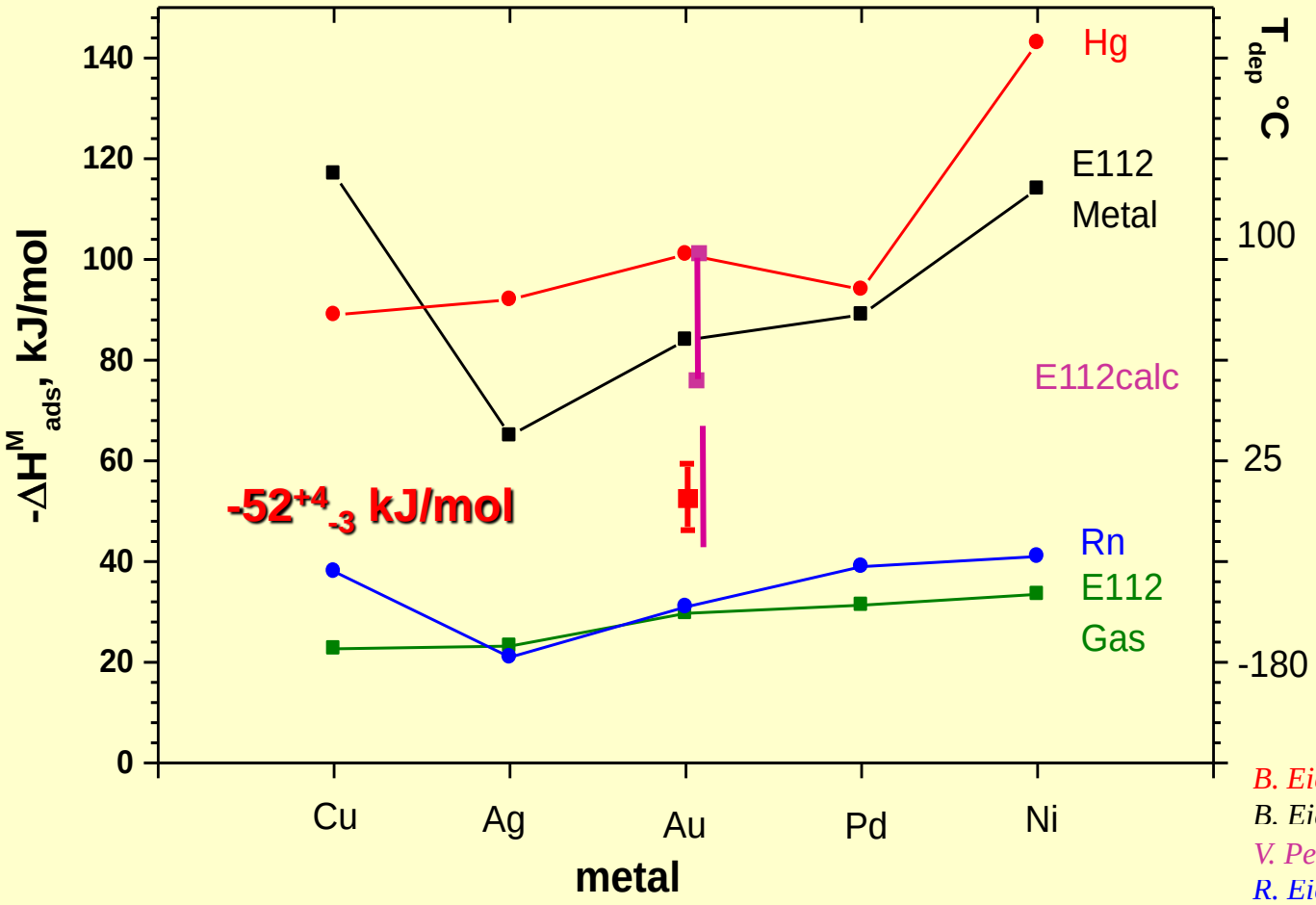


Experiment *Results* Simulation -52 kJ/mol





The Adsorption of Cn on Gold



B. Eichler 1985
B. Eichler 2003
V. Pershina et al. 2009/10
R. Eichler et al. 2002
R. Eichler et al. 2002

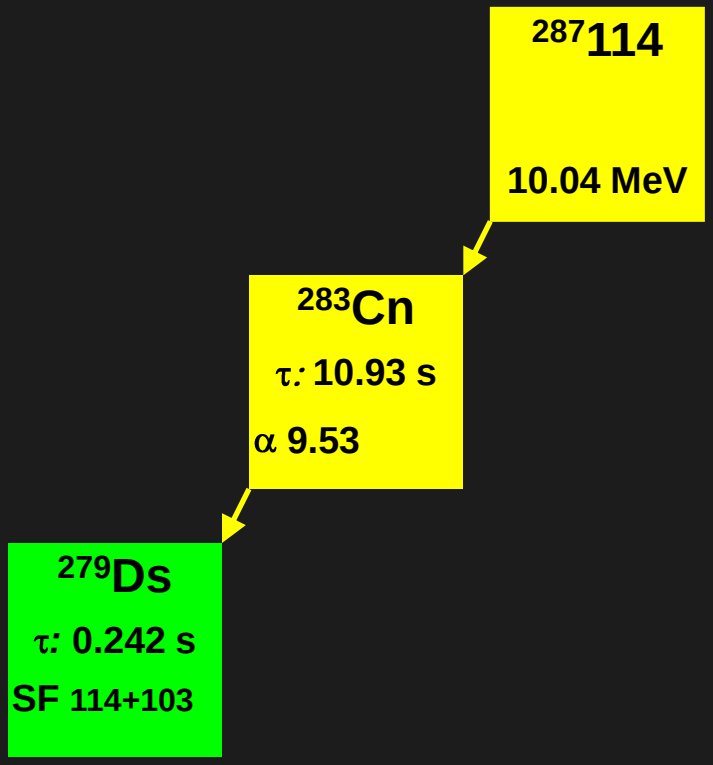
Eichler, R. et al. *Nature* 447, 72 (2007)

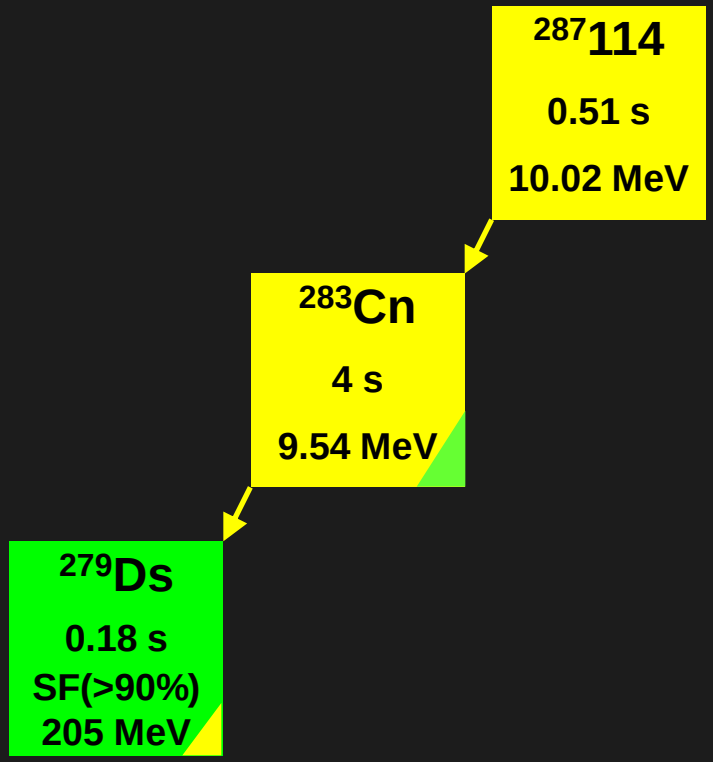
Results

Dubna 2007

^{242}Pu (^{48}Ca, 3n) ^{287}114

3.1•10^{18} ^{48}Ca during 16 days





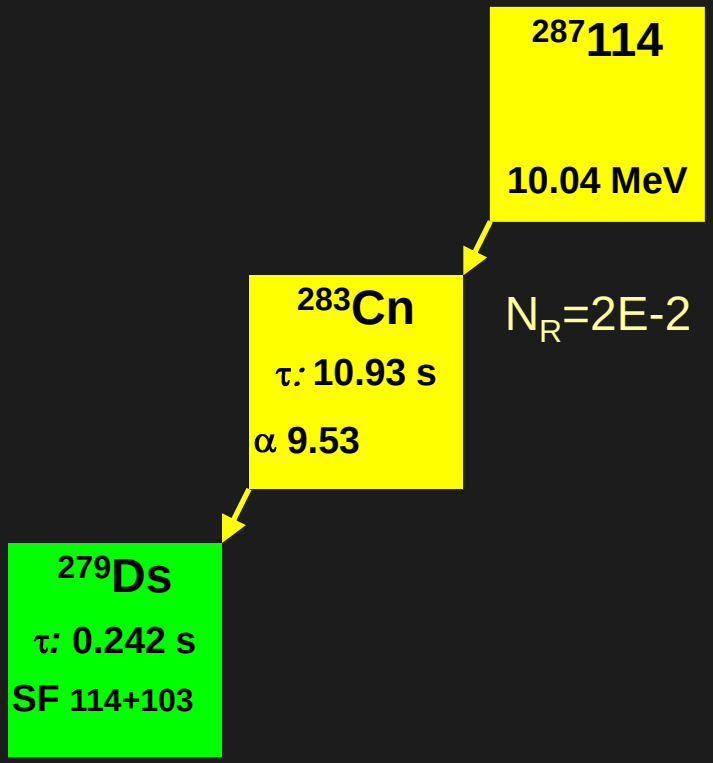
Oganessian, Yu. Ts. J. Phys. G 34, R165 (2007).

Results

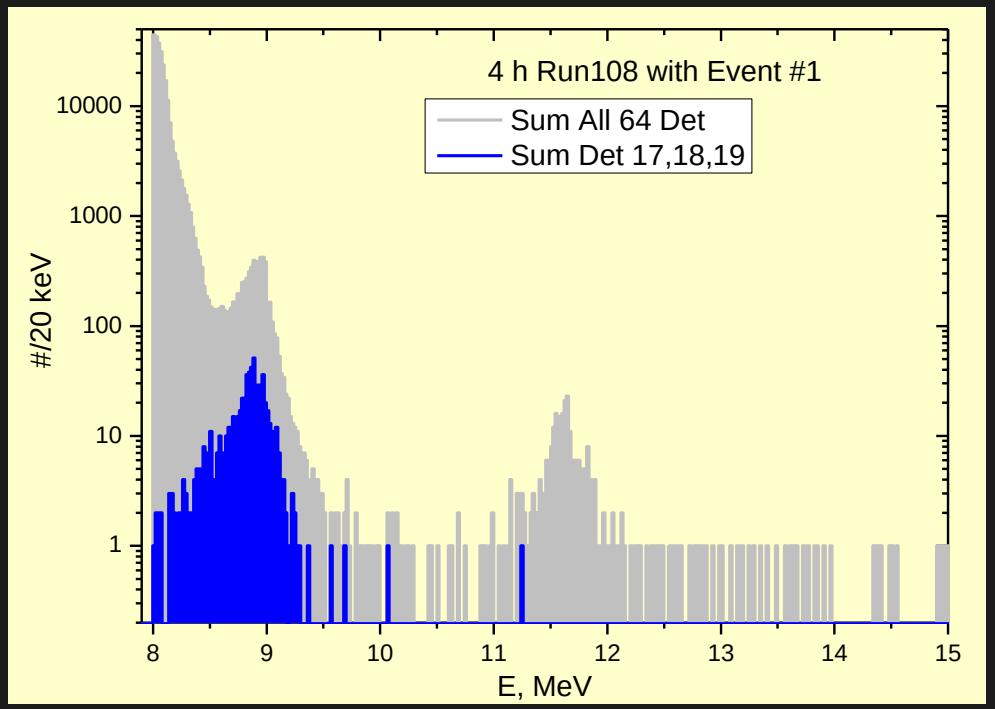
Dubna 2007

^{242}Pu (^{48}Ca, 3n) ^{287}114

3.1•10^{18} ^{48}Ca during 16 days



N_R=2E-2



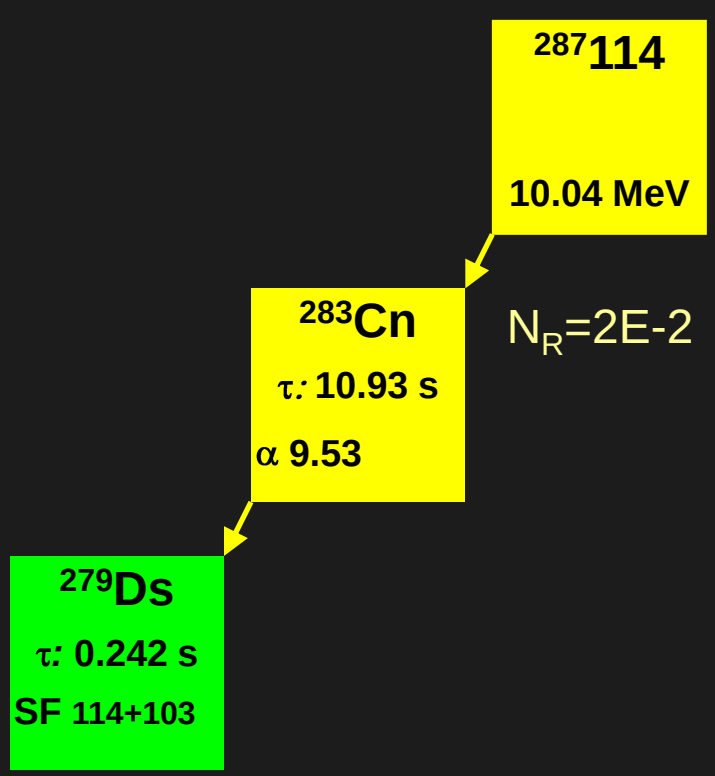
Results

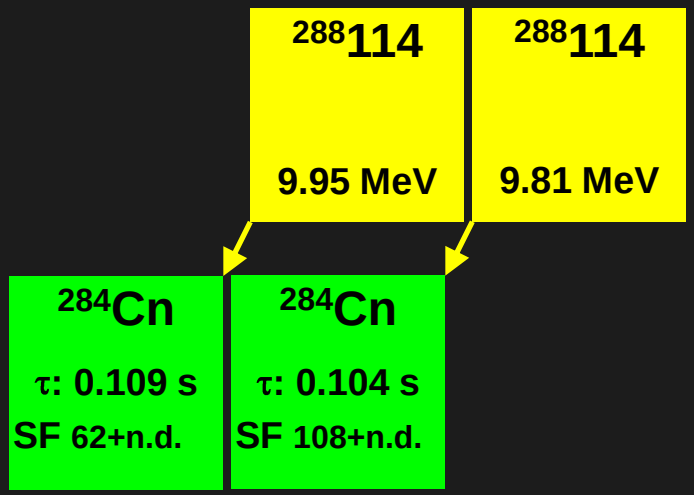
Dubna 2007

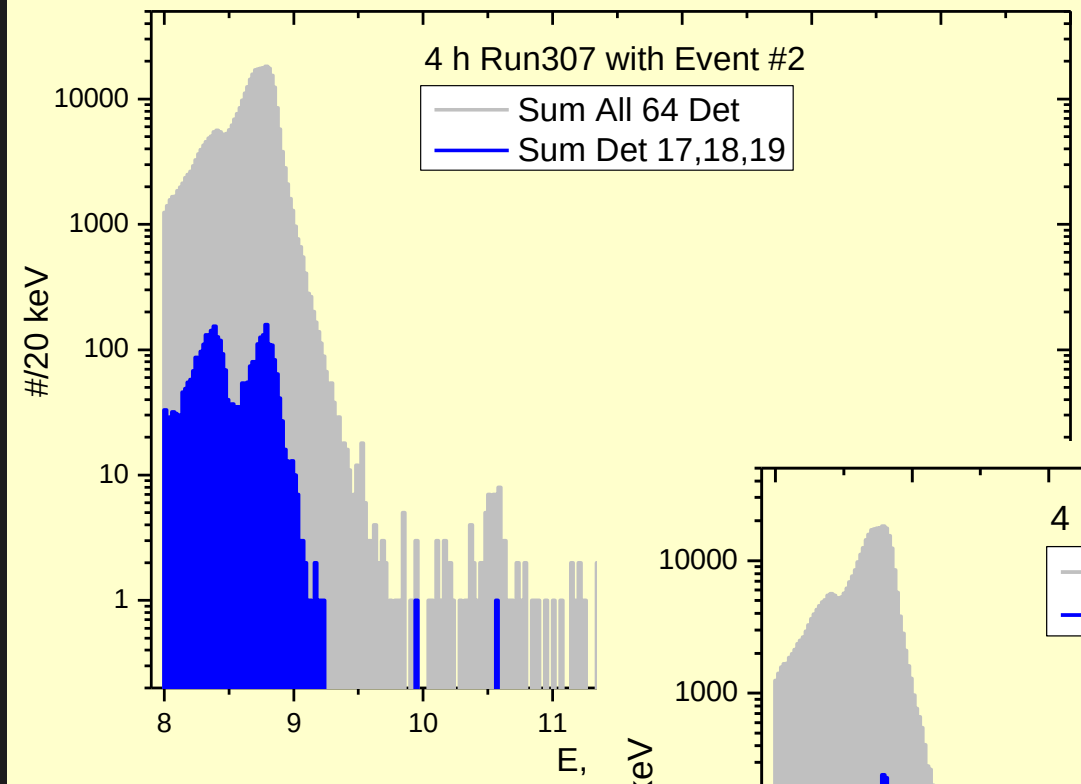
$^{242}Pu\ (^{48}Ca,\ 3n)\ ^{287}114$ ⟹ $^{244}Pu_{LLNL}\ (^{48}Ca,\ 3\text{-}4n)\ ^{288\text{-}289}114$

3.1•10^{18} ^{48}Ca during 16 days

4.5 •10^{18} ^{48}Ca during 16 days







^{288}114

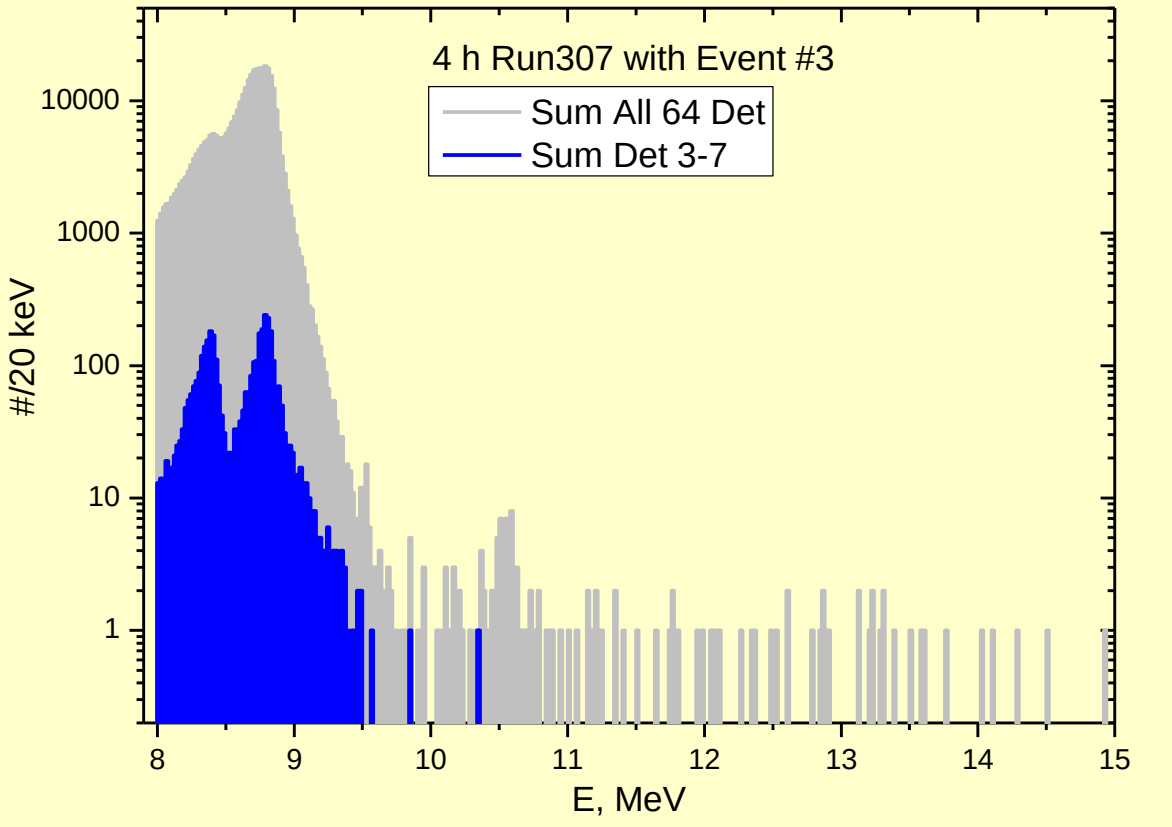
9.95 MeV

^{284}Cn

τ: 0.109 s

SF 62+n.d.

N_R=1.5E-3



^{288}114

9.81 MeV

D

^{284}Cn

τ: 0.104 s

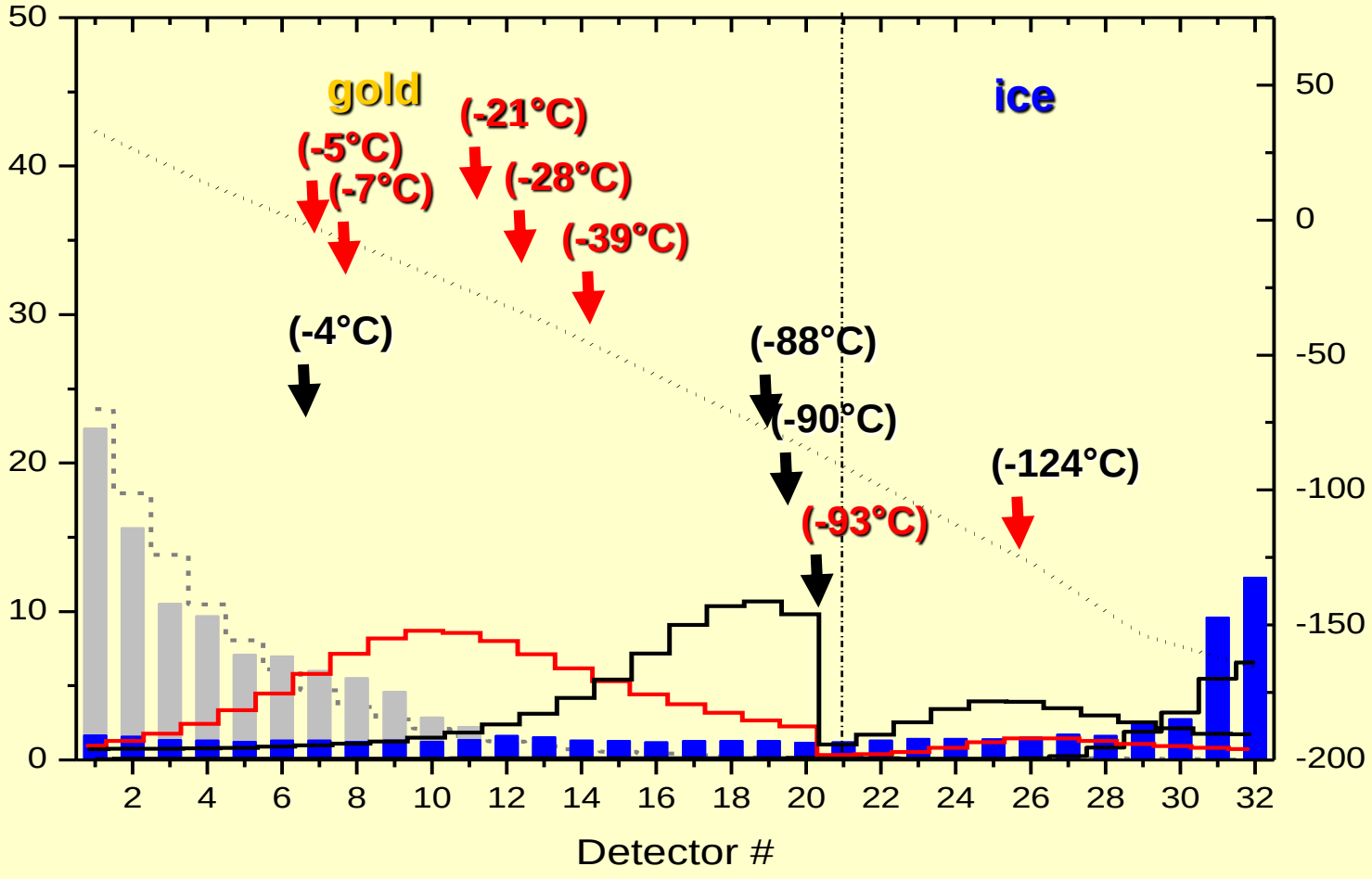
SF 108+n.d.

N_R=1.1E-2

Det#6

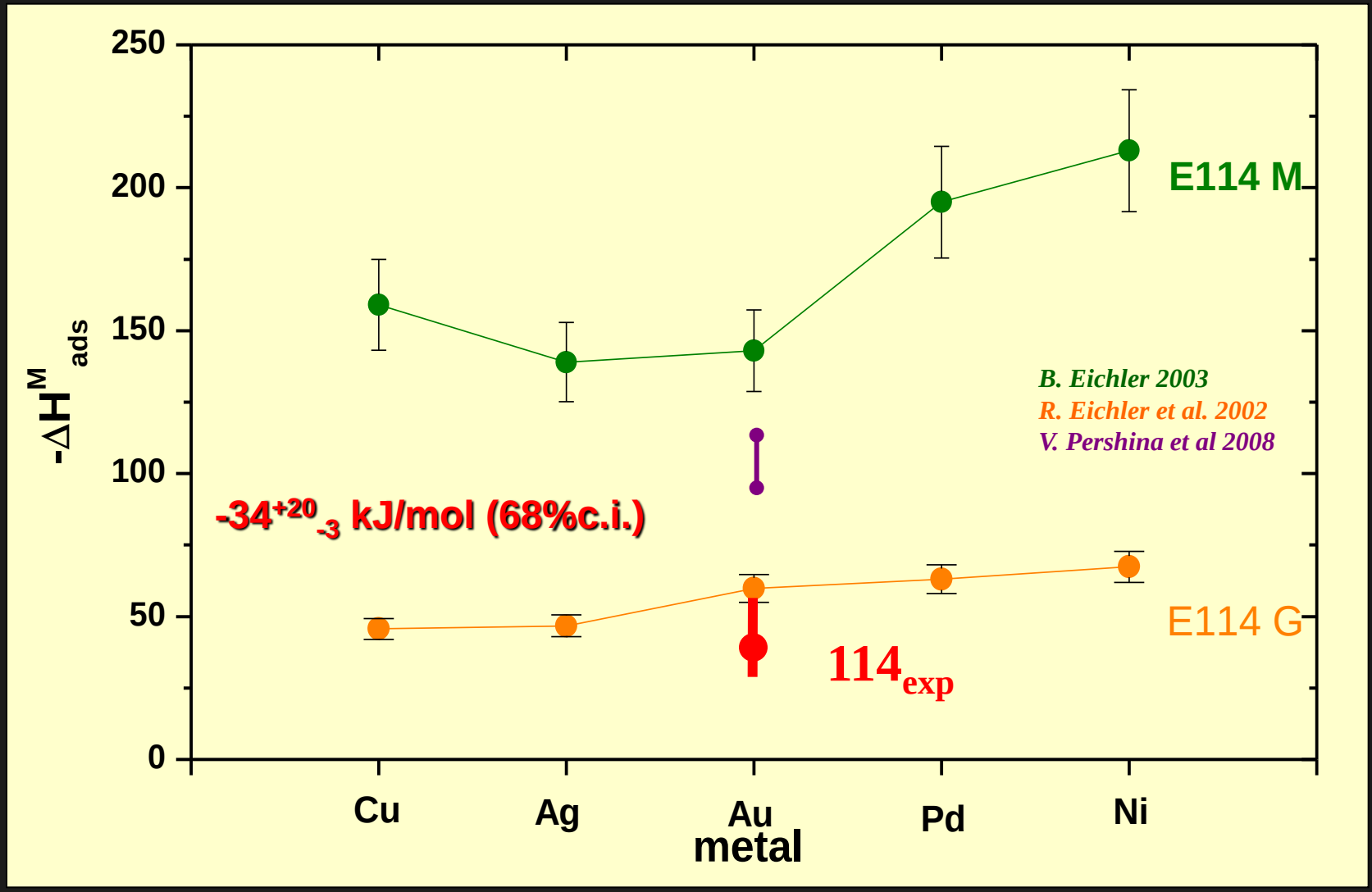
Results Cn+114 (2006-2011)

Pb ~1000°C (<<<) Hg ~ 200°C << Cn -25°C < 114 -90°C < Rn -170°C



Results 114

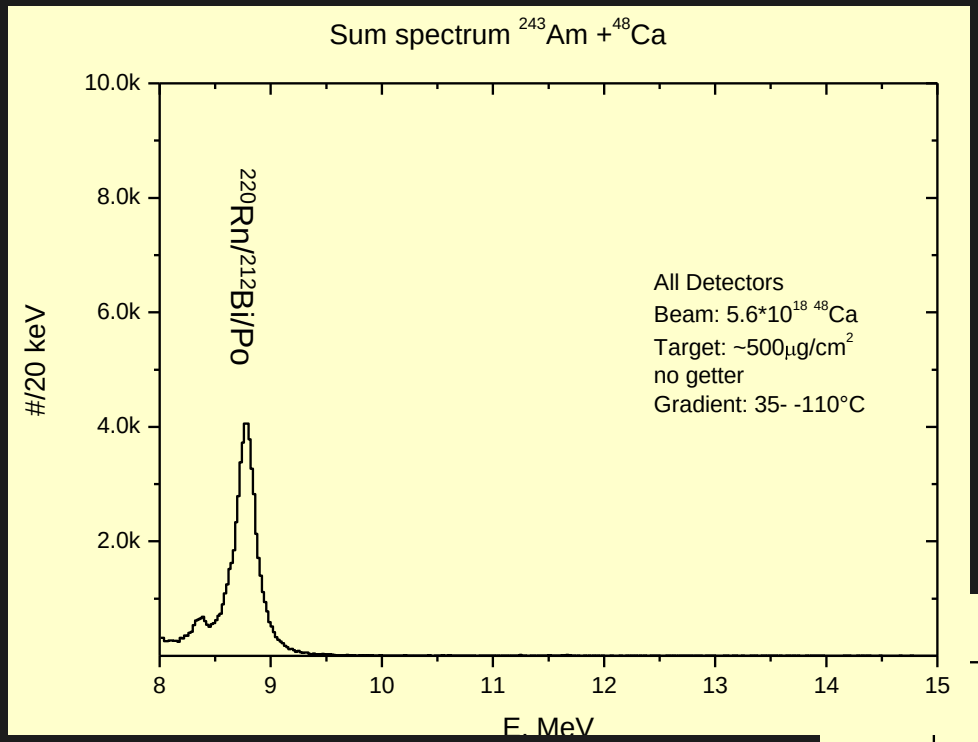
Results

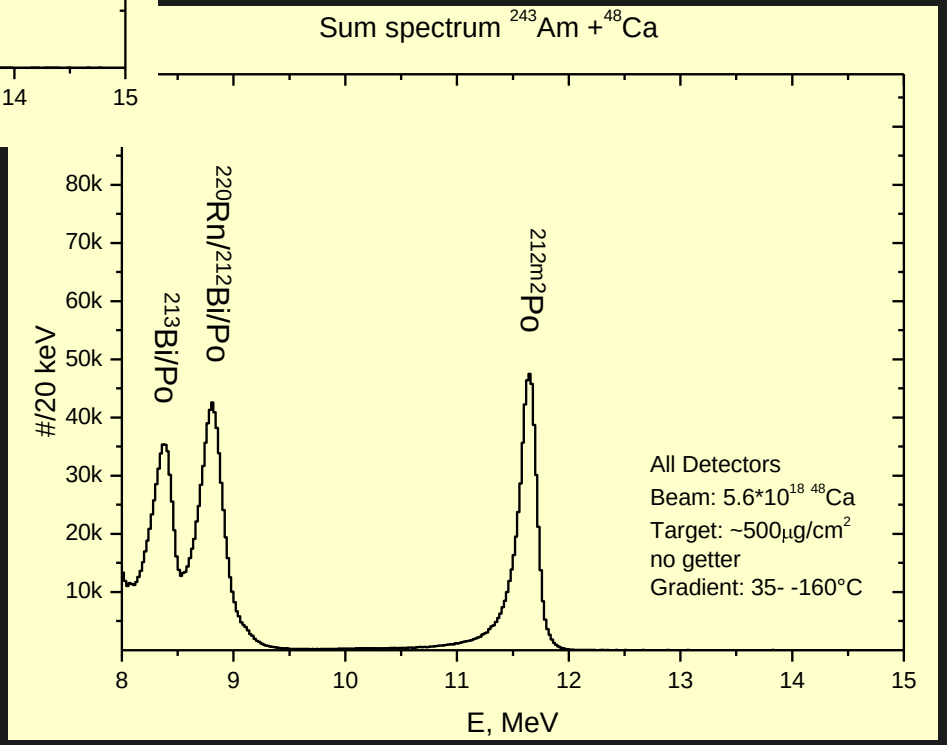


Indication for a strong stabilization of elemental atomic state for Element 114!

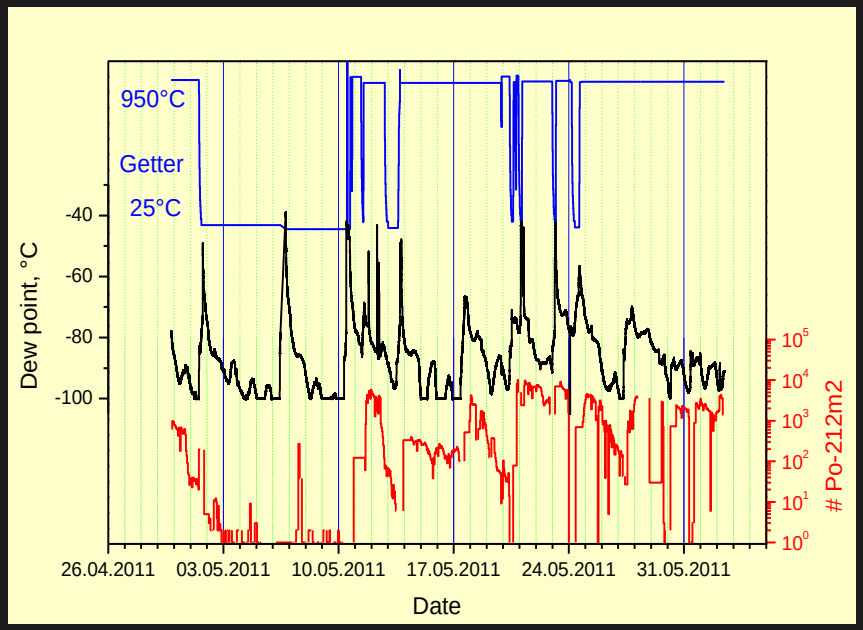
Eichler, R. et al. Radiochim.Acta, 98, 301 (2010).

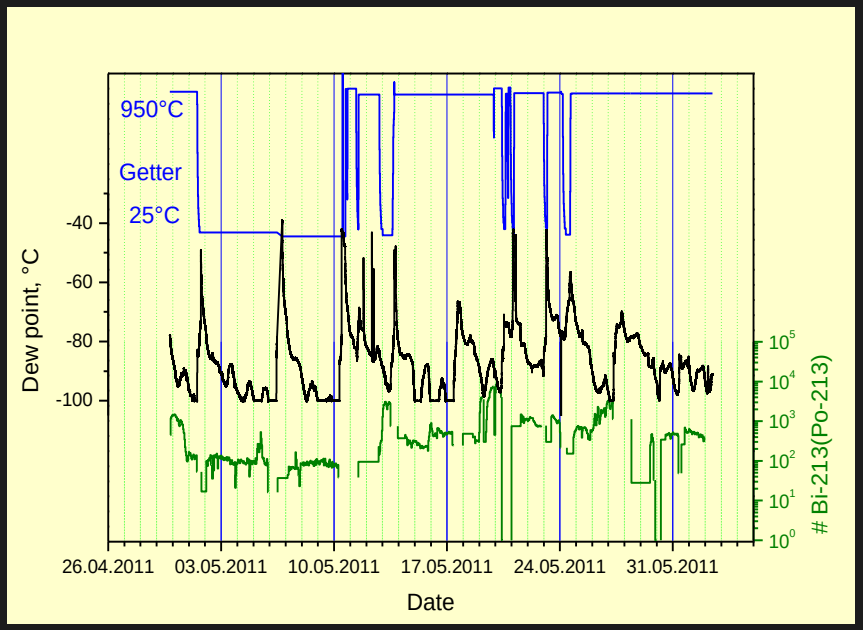
On the revival of an “old” compound class


Sum spectrum ^{243}Am +^{48}Ca
10.0k
8.0k
6.0k
4.0k
2.0k
#/20 keV
^{220}Rn/^{212}Bi/Po
All Detectors
Beam: 5.6*10^{18} ^{48}Ca
Target: ~500μg/cm^2
no getter
Gradient: 35- -110°C
8
9
10
11
12
13
14
15
E, MeV

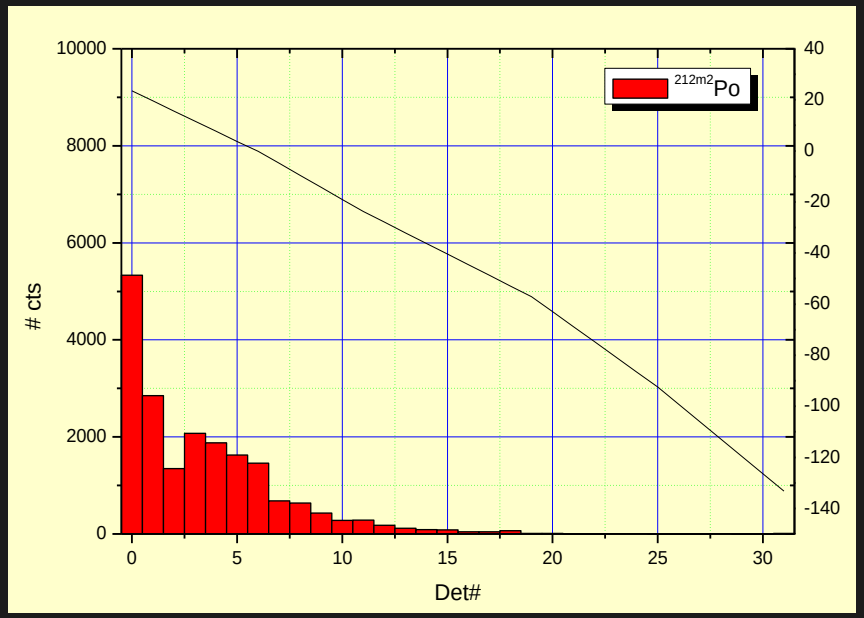

Sum spectrum ^{243}Am +^{48}Ca
80k
70k
60k
50k
40k
30k
20k
10k
#/20 keV
^{213}Bi/Po
^{220}Rn/^{212}Bi/Po
^{212m2}Po
All Detectors
Beam: 5.6*10^{18} ^{48}Ca
Target: ~500μg/cm^2
no getter
Gradient: 35- -160°C
8
9
10
11
12
13
14
15
E, MeV

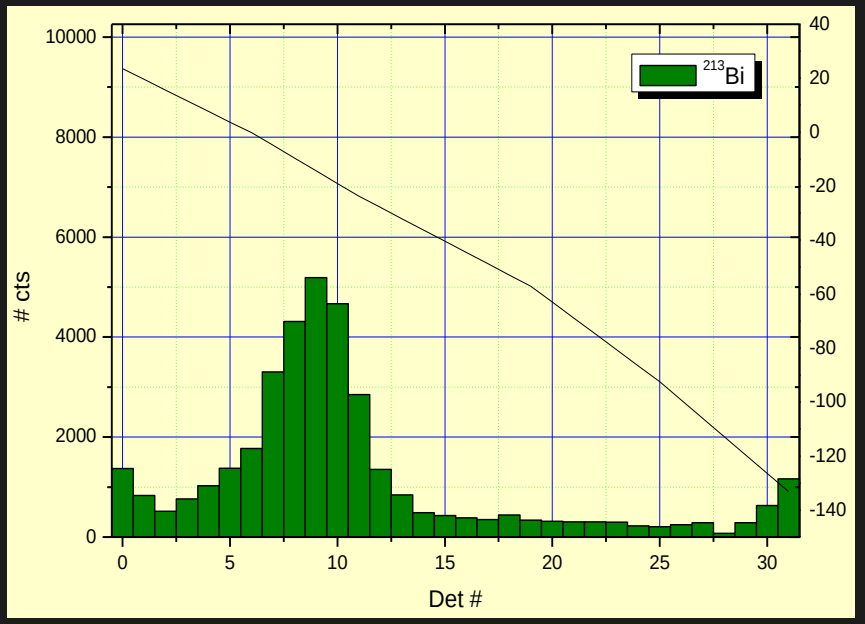
Correlation to Dew point and Getter





Thermochromatograms of PoH_2 and BiH_3





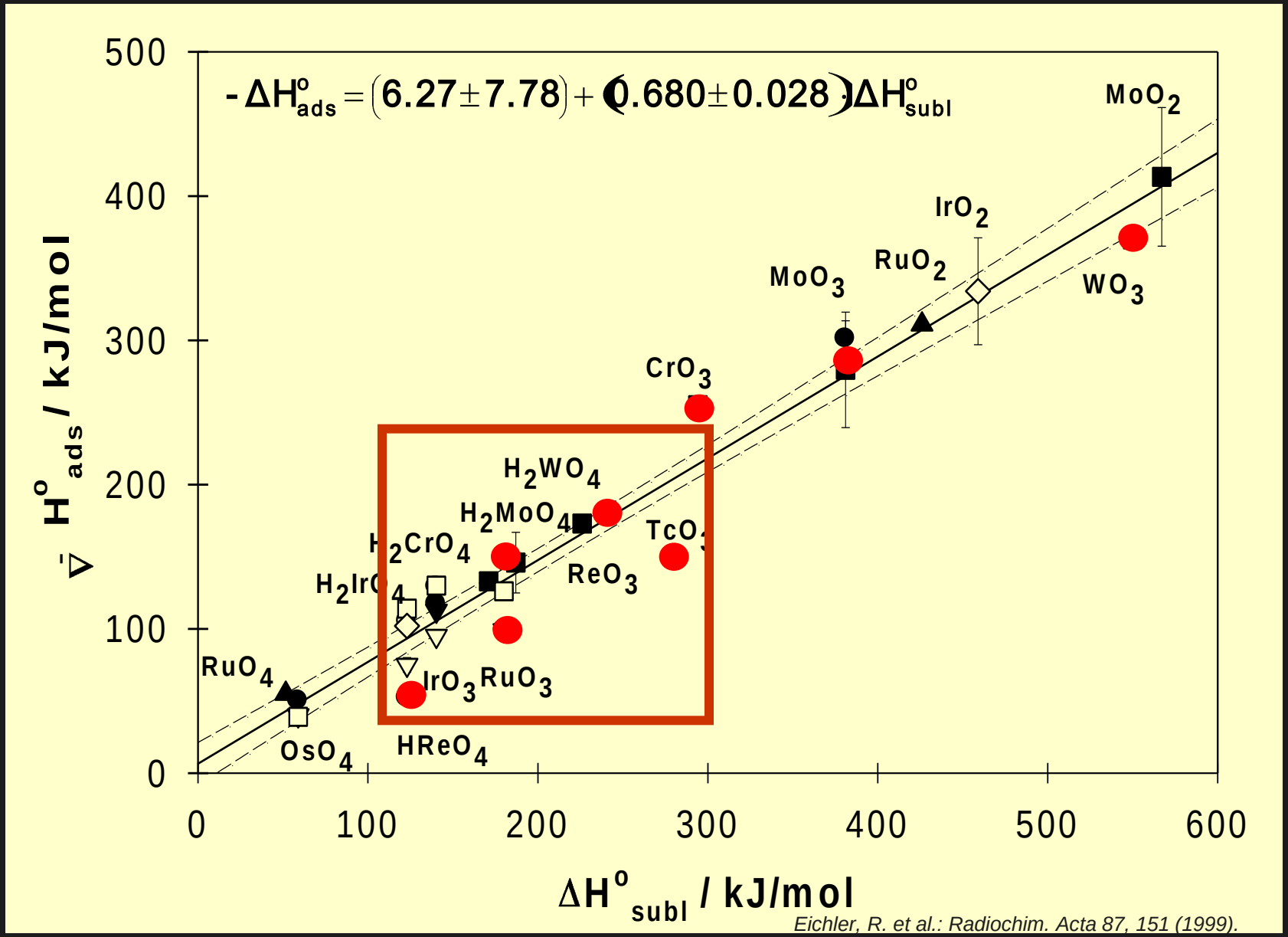
Chemistry of Transactinides

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	113	114	115	116	117	118

*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

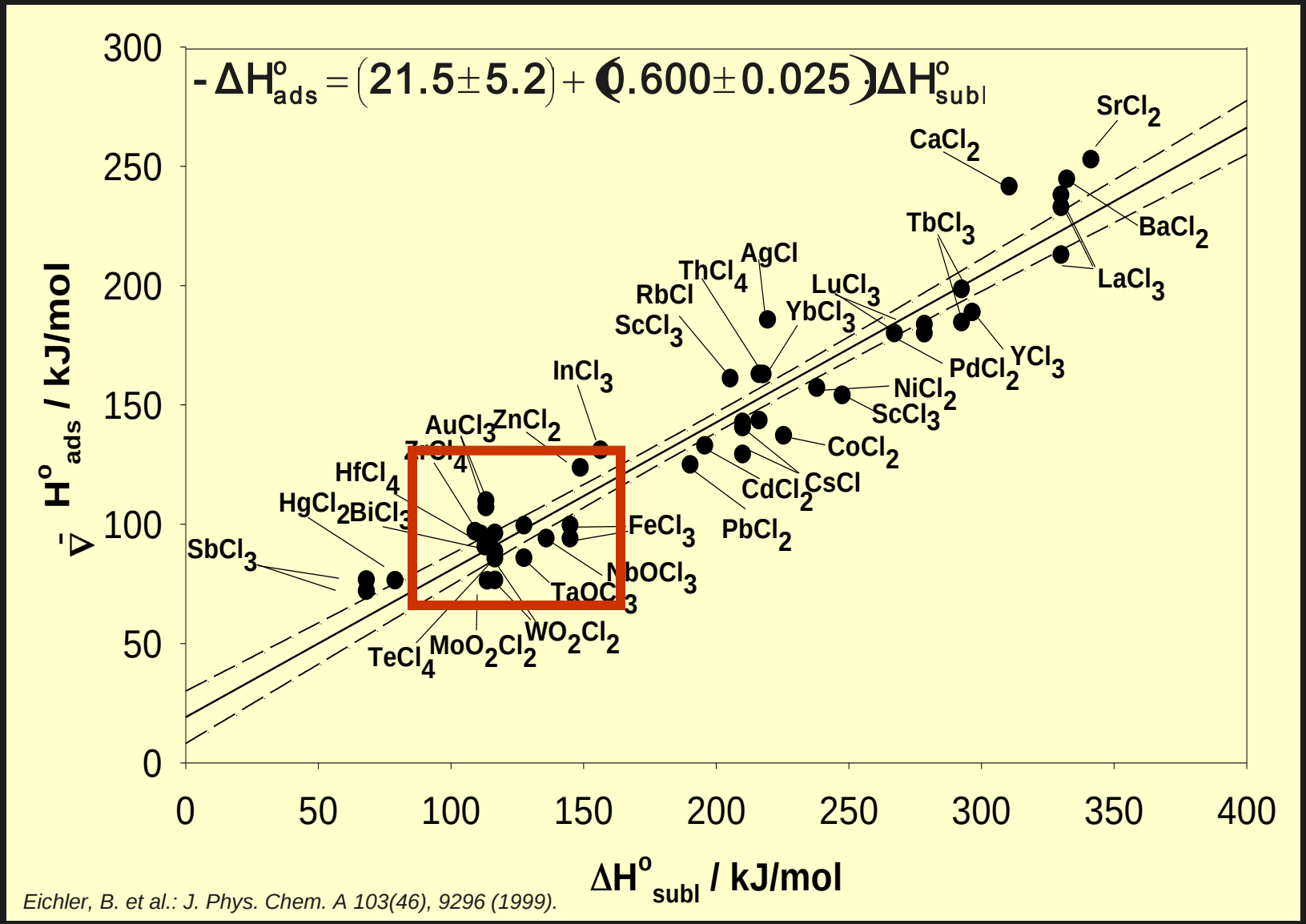
On the empirical correlations of microscopic to macroscopic data

Oxides/Oxohydroxides on quartz



Eichler, R. et al.: Radiochim. Acta 87, 151 (1999).

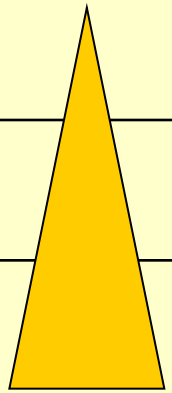
Chlorides/Oxochlorides on quartz



Eichler, B. et al.: J. Phys. Chem. A 103(46), 9296 (1999).

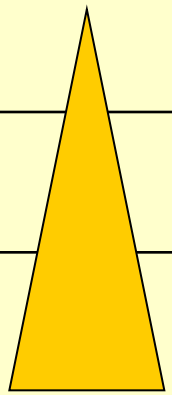
$-\Delta H_{ads}$, kJ/mol

Group	6	7	8
	MoO_2Cl_2 90	TcO_3Cl 51	RuO_4 ?
	WO_2Cl_2 96	ReO_3Cl 61	OsO_4 39
	SgO_2Cl_2 98	BhO_3Cl 75	HsO_4 46

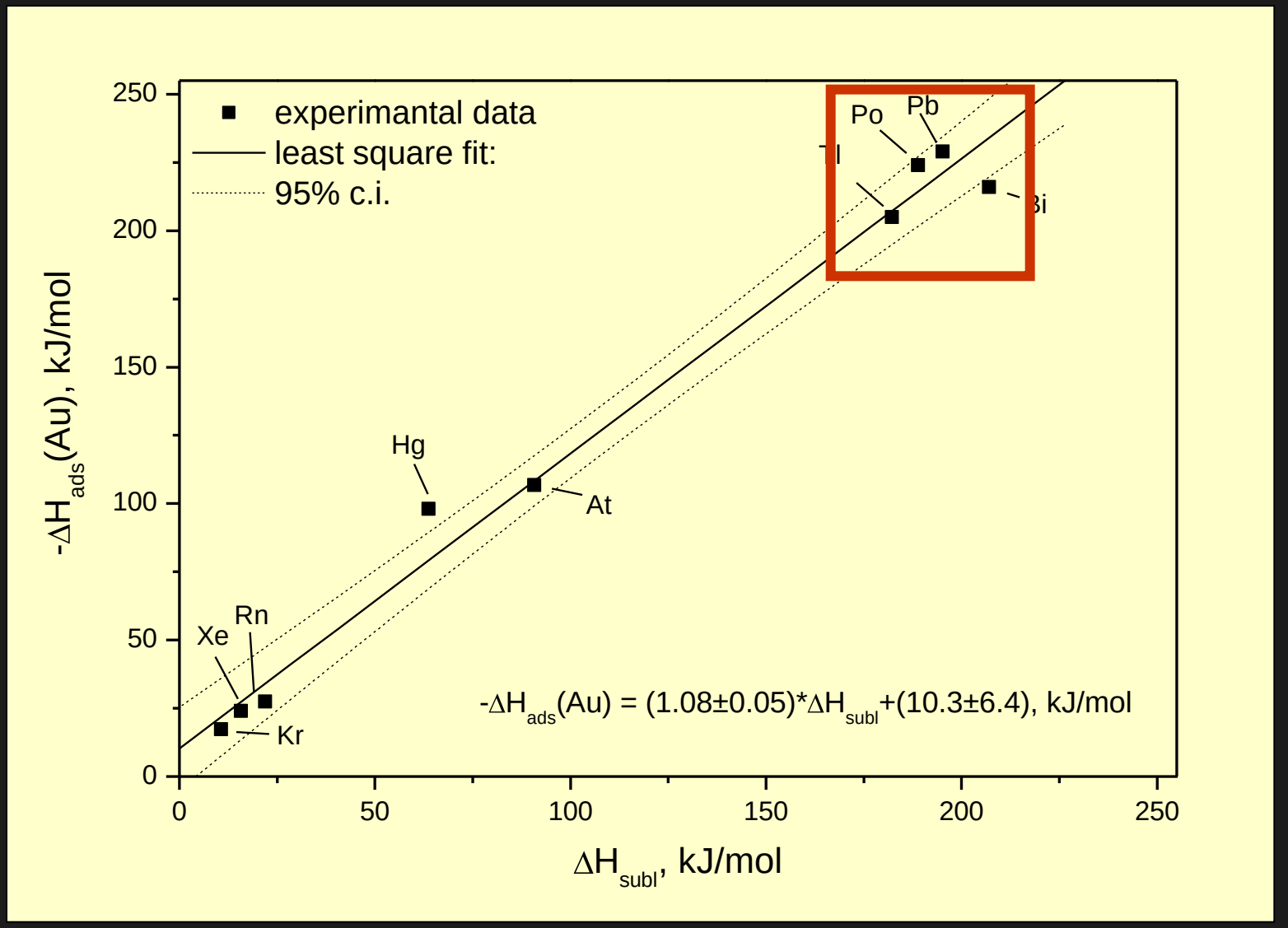


ΔH_{subl}, kJ/mol

Group	6	7	8
	MoO_2Cl_2 93	TcO_3Cl 49	RuO_4 52
	WO_2Cl_2 109	ReO_3Cl 68	OsO_4 57
	SgO_2Cl_2 127	BhO_3Cl 89	HsO_4 58

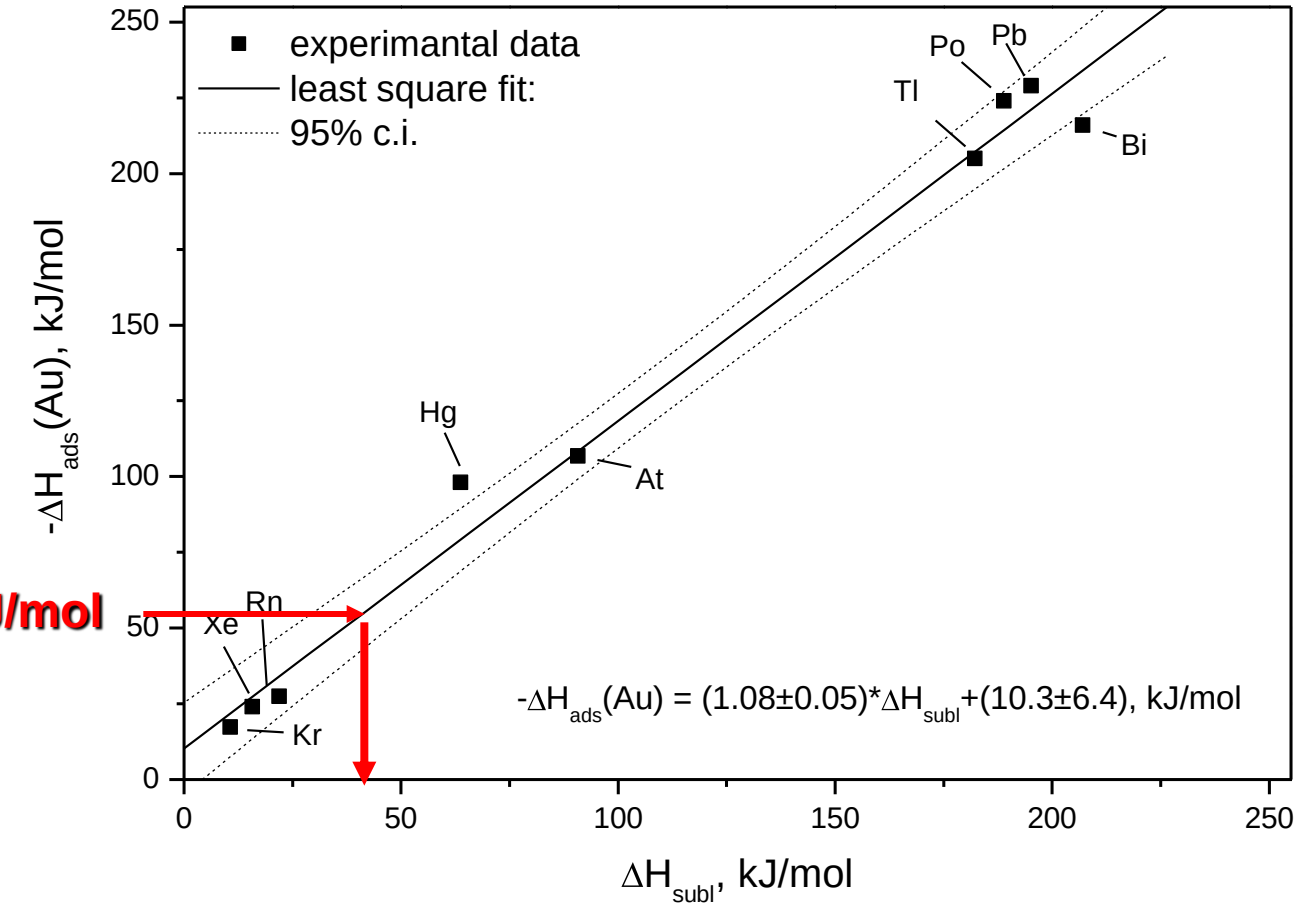


Elements on gold *(experiments)*



R. Eichler Radiochim. Acta 93, 245–248 (2005)

Adsorption → Sublimation (volatility) Cn



-52^{+4}_{-3} kJ/mol

$\Delta H_{subl} = 38^{+12}_{-10}$ kJ/mol (68% c.i.)

Volatility of Cn

Eichler: Das Flüchtigkeitsverhalten von Transactiniden im Bereich um $Z = 114$ (Voraussage)

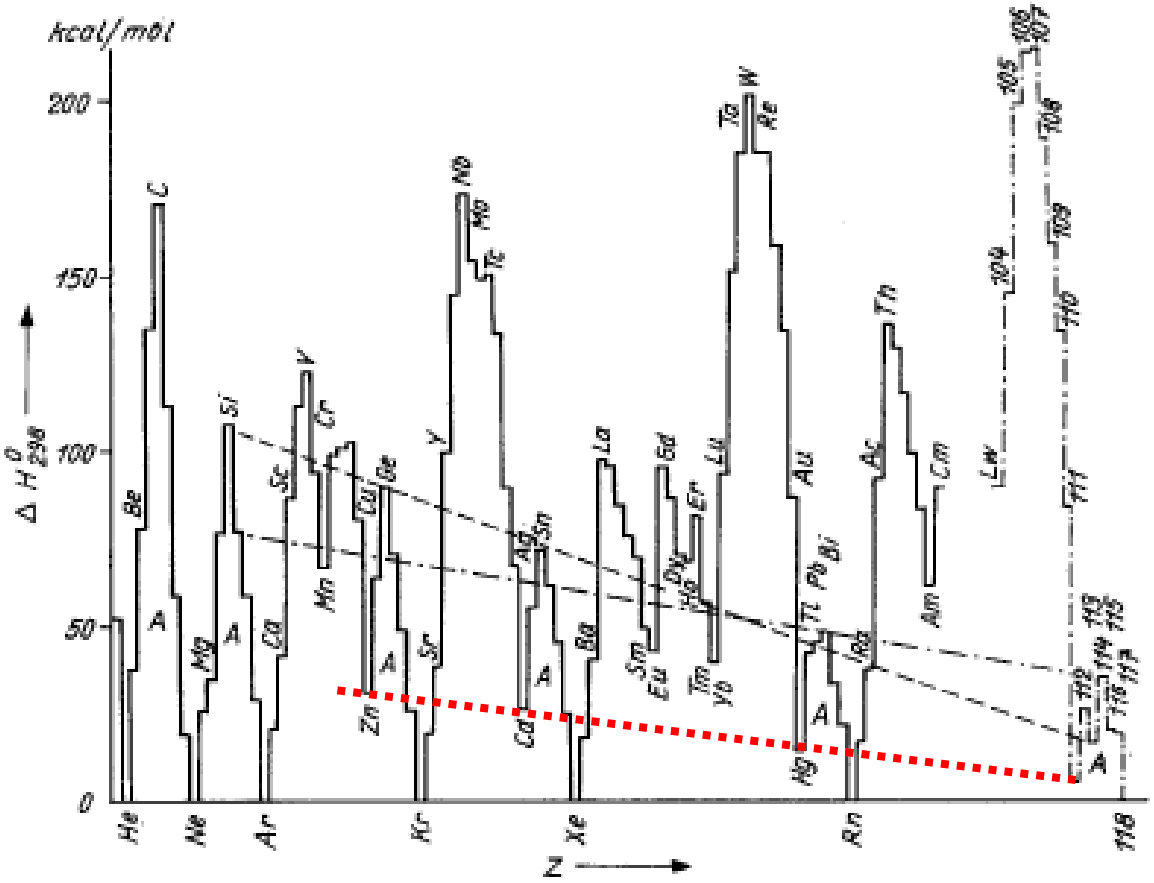
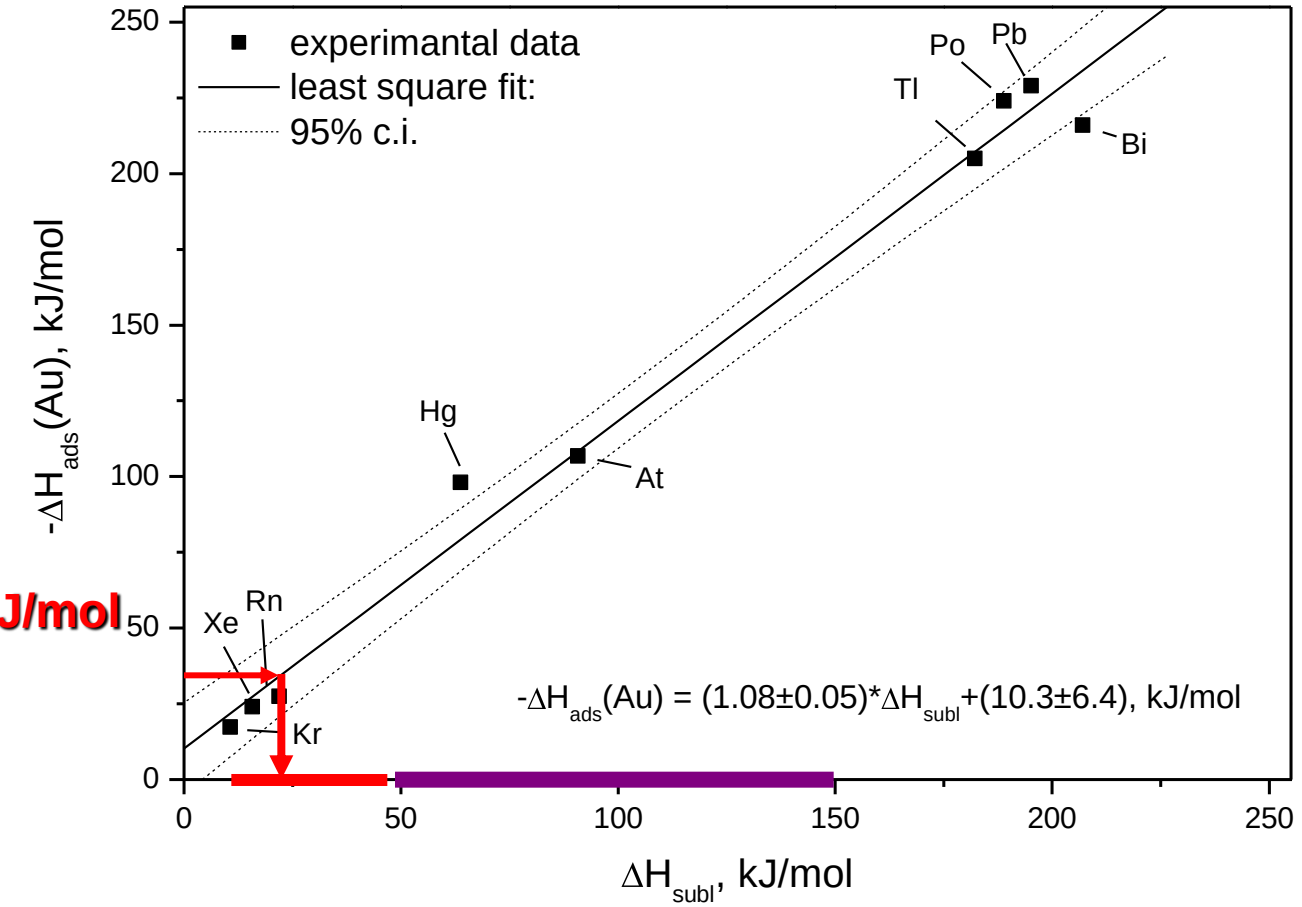


Abb. 1. Standardenthalpien ΔH°_{298} (g, a) der gasförmigen monoatomaren Elemente in Abhängigkeit von der Ordnungszahl Z

„Kernenergie" 19. Jahrgang · Heft 10/1976

Eichler, R. et al. *Angew. Chem. Int. Ed.* 47, 3262 (2008)

Adsorption → Sublimation (volatility) E114



-34^{+20}_{-3} kJ/mol

$\Delta H_{subl}(114) = 23^{+21}_{-8}$ kJ/mol (68% c.i.)

Empirical Correlations !

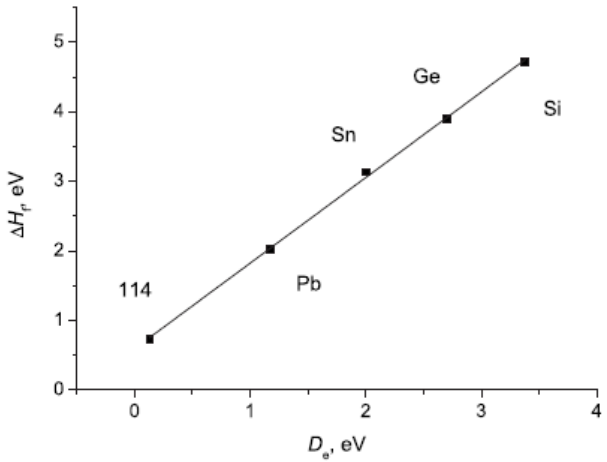
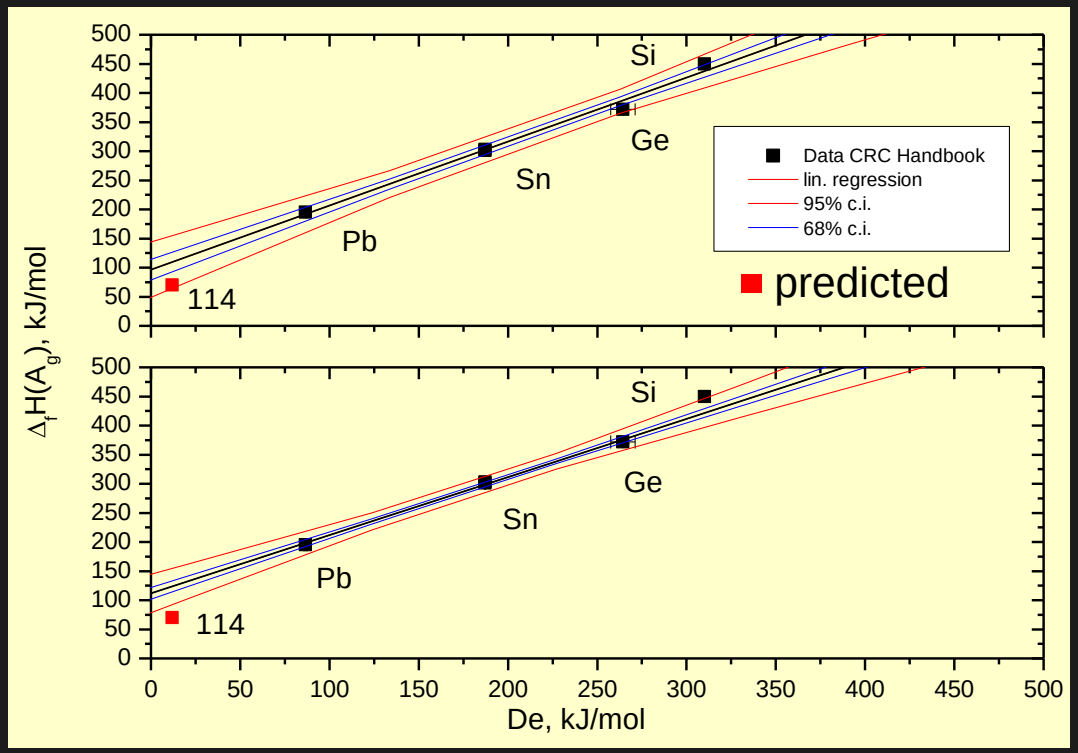


FIG. 8. Correlation between formation enthalpies $\Delta H_f(g)$ (Ref. 15) and dissociation energies $D_e(M_2)$ of group 14 elements (experimental values for Si–Pb, and calculated for element 114, see Table I).

THE JOURNAL OF CHEMICAL PHYSICS 132, 194314 (2010)

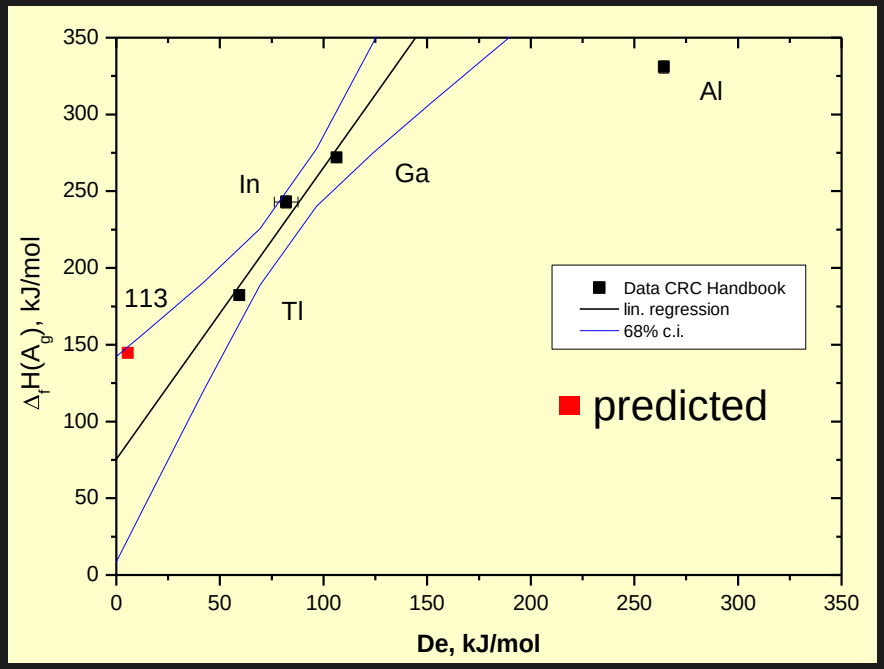
Theoretical predictions of trends in spectroscopic properties of homonuclear dimers and volatility of the 7p elements

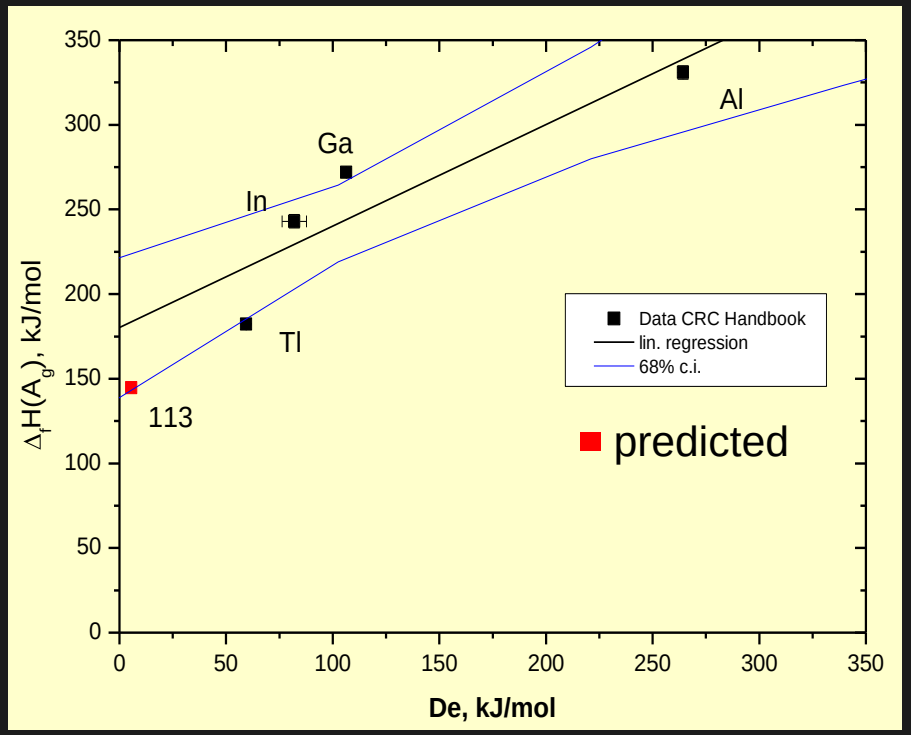
V. Pershina,[1,a)] A. Borschevsky,[1,2] J. Anton,[3] and T. Jacob[3]



$$\Delta H_{subl}(114) = 23^{+21}_{-8}\ \text{kJ/mol (68\% c.i.)}$$

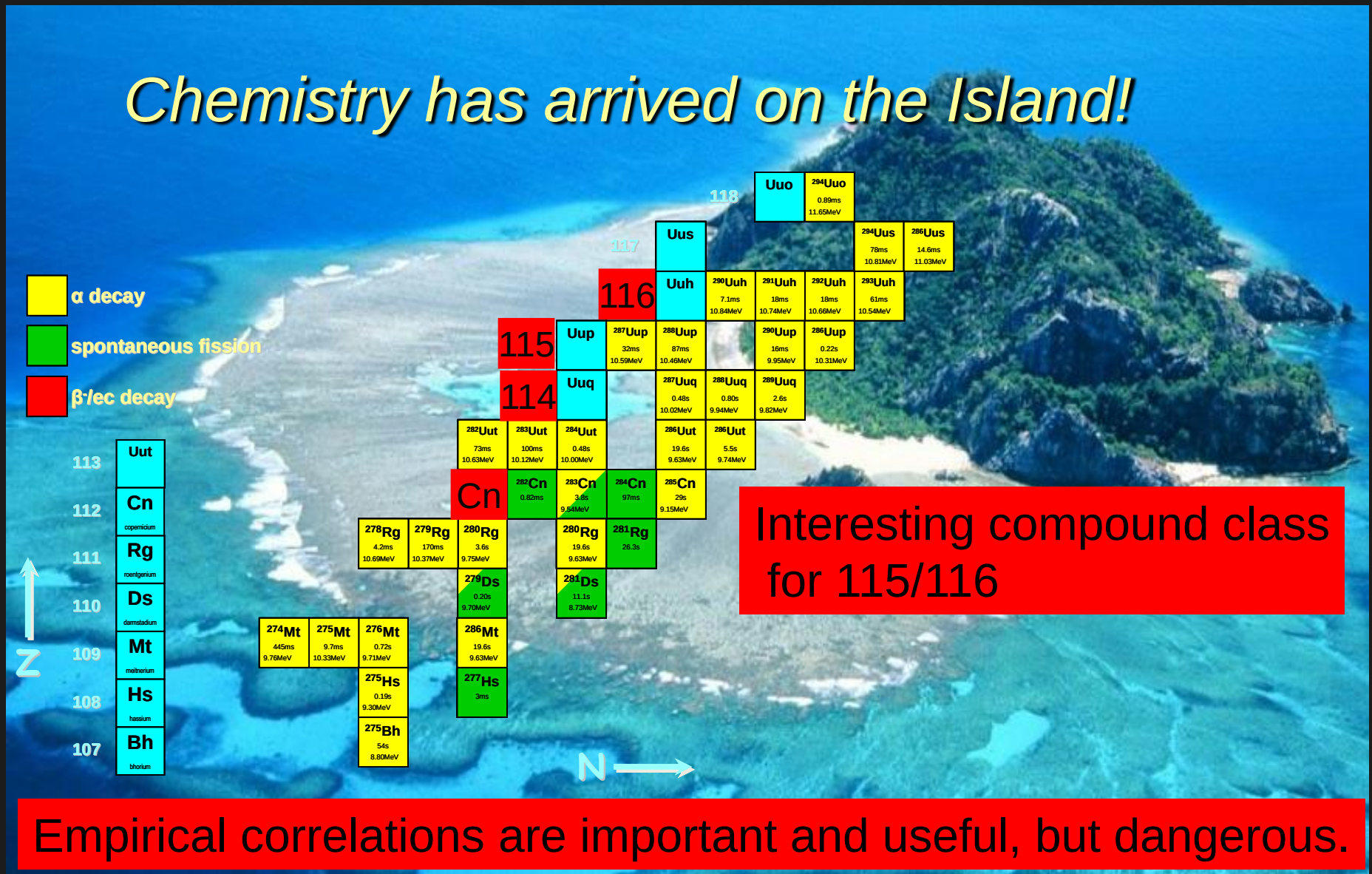
Empirical Correlations for Group 13 !?





Summary

Chemistry has arrived on the Island!



Empirical correlations are important and useful, but dangerous.

Acknowledgements

Accelerator and ECR crews:

U400, Philips cyclotron

LMN, Electronics group @ PSI

Tech-shops @ University Bern, PSI, FLNR

US Department of Energy (^{244}Pu)

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U$ Department of Energy

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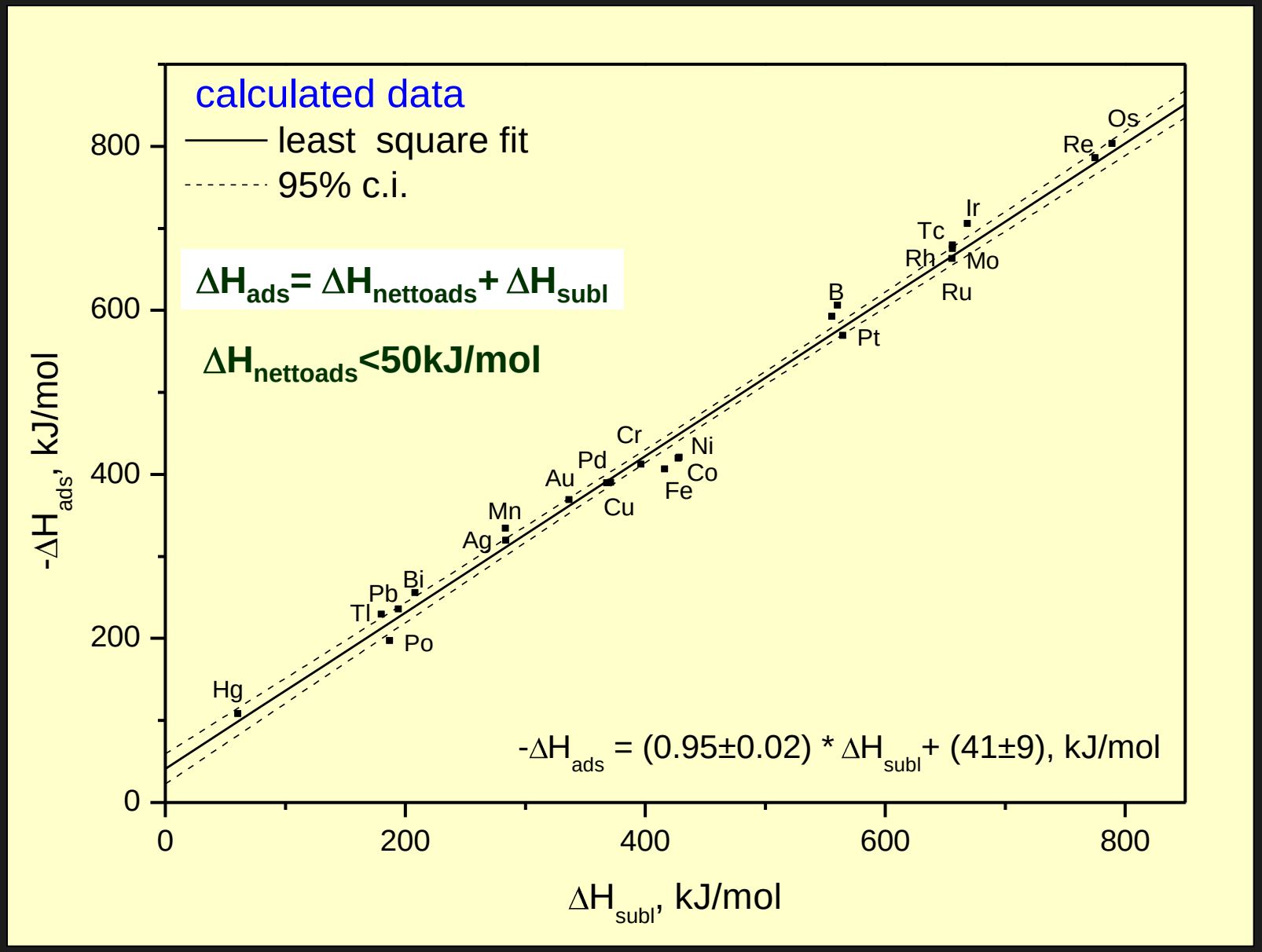
Elements on gold *(calculations)*



Target failure 2011