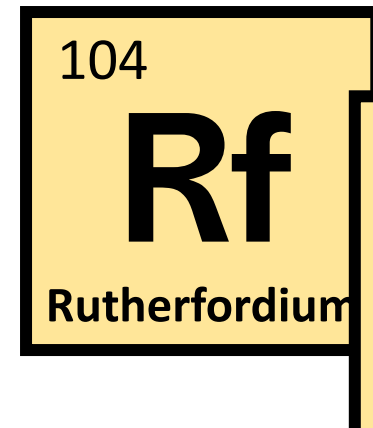


Chemical characterization of the heaviest elements and their homologues

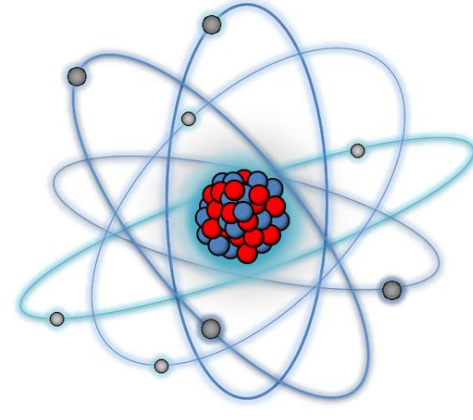
Katharina Hermainski

FB 09, Department Chemie - TRIGA site, supervised by Prof. Dr. Christoph Düllmann

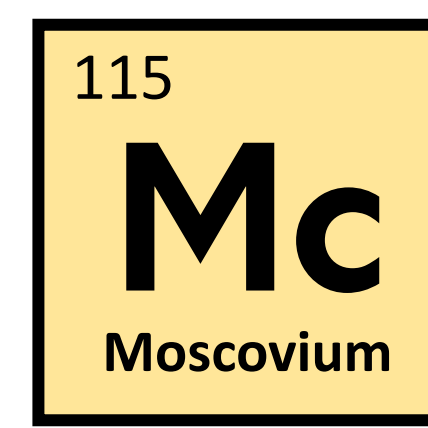
Chemistry at the heavy-element frontier: The study of superheavy elements



Elements rutherfordium (element 104) to oganesson (element 118) are called superheavy elements (SHEs).



Owing to their high nuclear charge, the chemistry of SHEs is strongly influenced by relativistic effects.¹



The heaviest element chemically studied to date is moscovium (element 115).²

Relativistic effects shape our elements

Our elements without relativistic effects:

1	2																	18																														
H	He																	Ne																														
3	4	5	6	7	8	9	10											18																														
Li	Be	B	C	N	O	F	Ne											Ar																														
11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36																							
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																							
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71														
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu														
87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118																	
Fr	Ra	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og																																
																	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150
																	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr																				

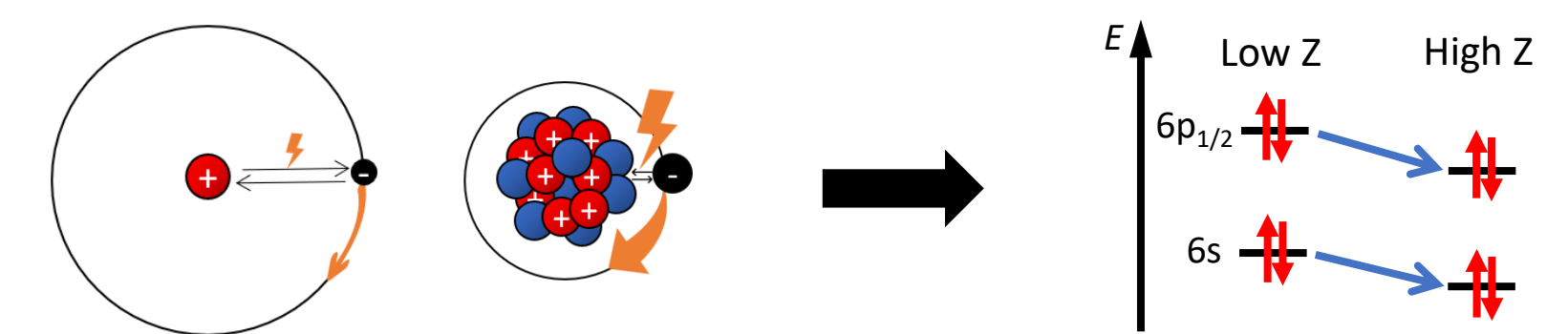
Au would have the same colour as Ag

Hg would not be liquid at room temperature

No cardio-SPECT with Tl would be possible

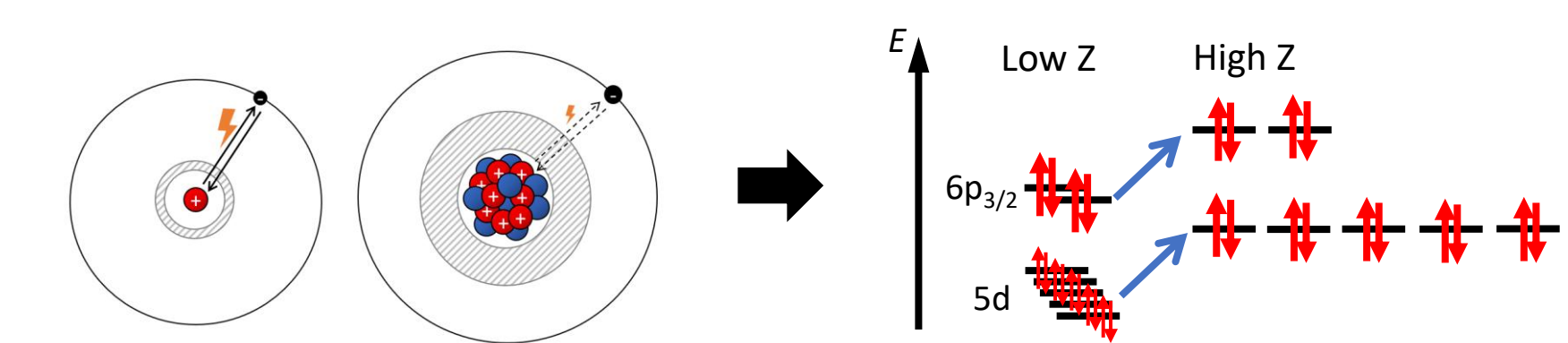
Lead car batteries would not exist

Direct relativistic effect



High atomic number Z leads to higher electron velocity in near-core electrons, contracting their orbitals.

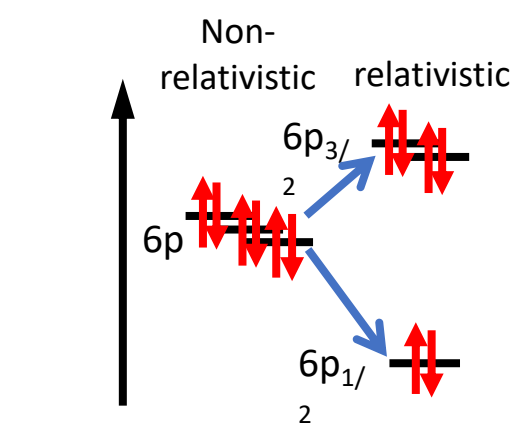
Indirect relativistic effect



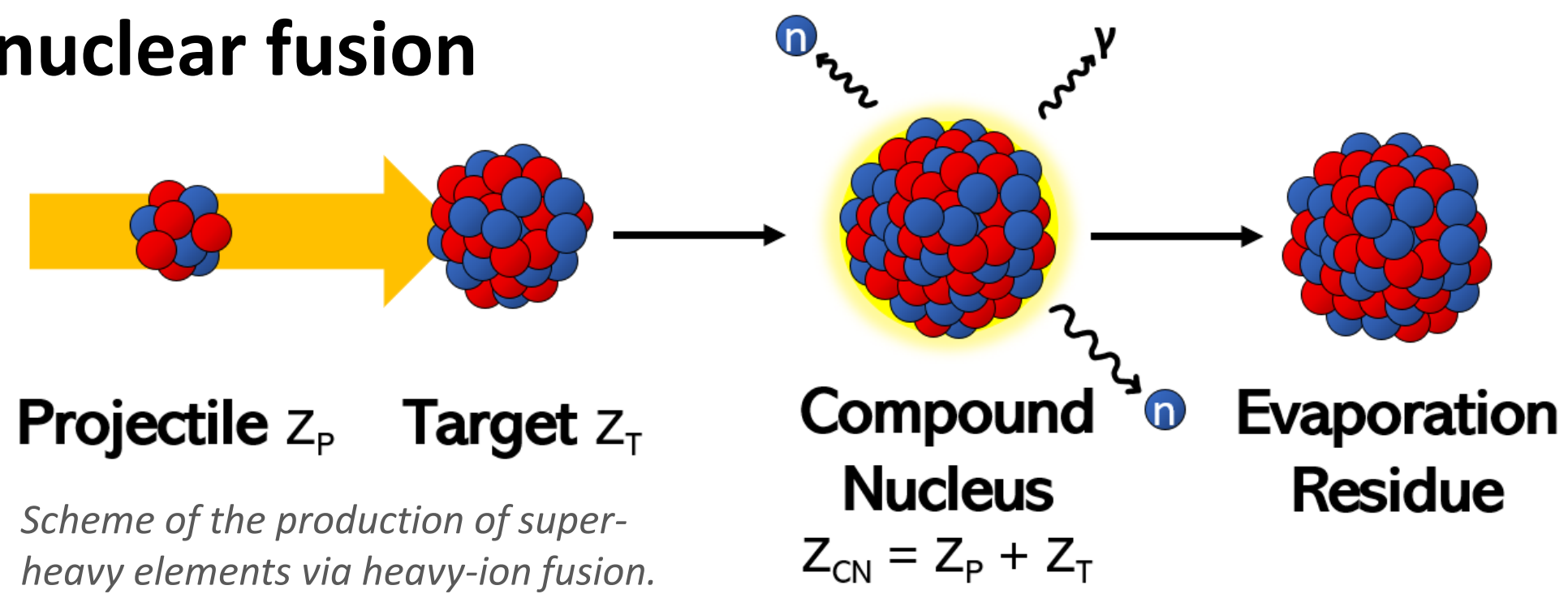
Nuclear charge is more strongly shielded by near-core orbitals, other orbitals expand.

Spin-orbit coupling

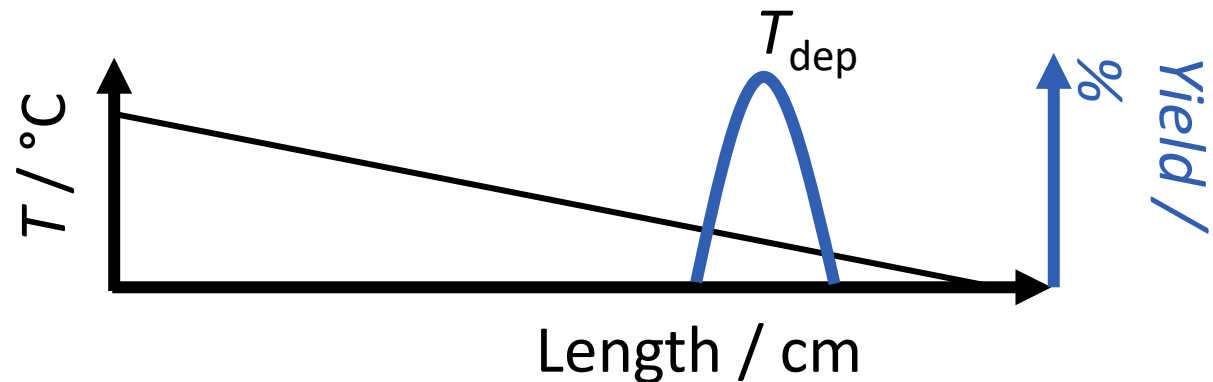
Orbitals are classified by \vec{j} and no longer by \vec{l} , shapes and energies of orbitals change.



Production of SHE atom-by-atom using nuclear fusion



Chemically studying single atoms with thermochromatography

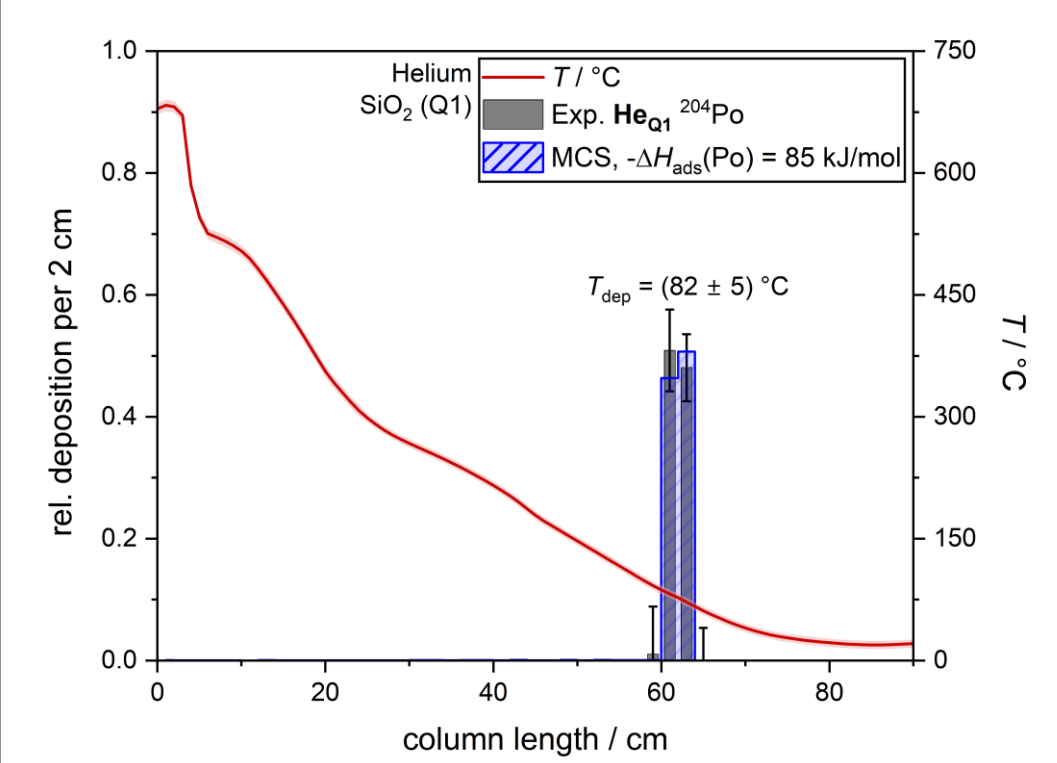


Thermochromatography: Measuring the deposition pattern of a chemical species along a temperature gradient.³

Monte Carlo Simulation

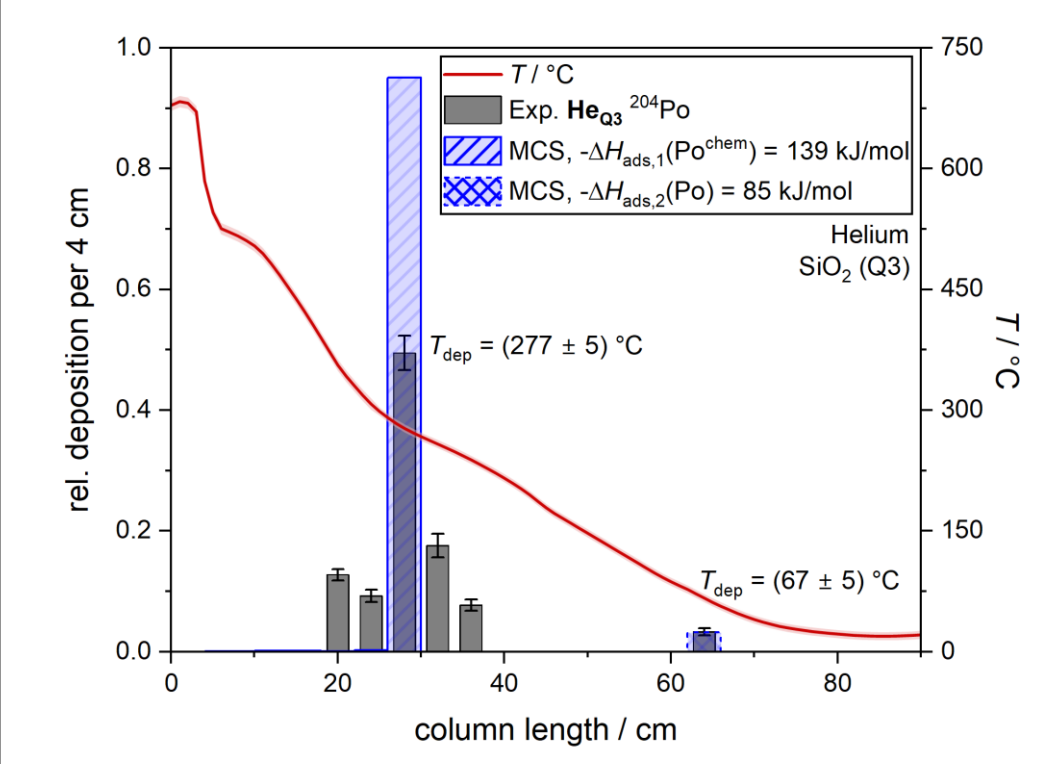
Determination of adsorption enthalpy $-\Delta H_{ads}$ from T_{dep} as a measure of an element's volatility and reactivity.⁴

Preparations for livermorium chemistry: Thermochromatography studies of polonium

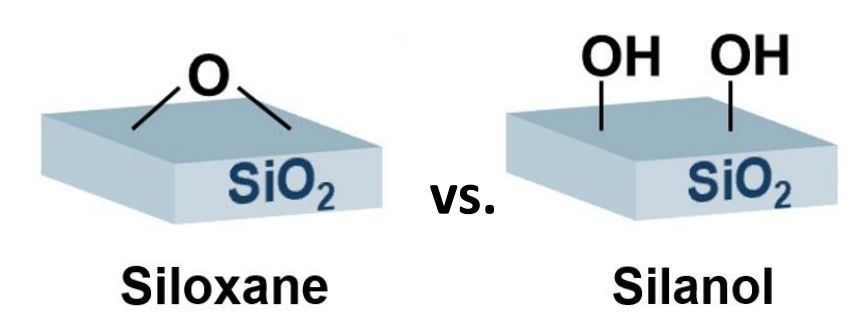


Elemental polonium was found to be the most volatile species on quartz:⁵

$$-\Delta H_{ads} = 85^{+3}_{-2} \text{ kJ/mol}$$



Polonium can react with OH-groups on the quartz surface, forming a low-volatile species.⁵



Experiments suggest to study livermorium in the elemental state.

References

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2. A. Yakushev et al., *Front. Chem.*, 2024, 12, 1474820
3. A. Türler and V. Pershina, *Chem. Rev.*, 2013, 113, 1237–1312
4. I. Zvara, *Radiochim. Acta*, 1985, 38, 95–101
5. K. Hermainski et al., *Phys. Chem. Chem. Phys.*, 2025, 27, 21414–21423

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