Towards livermorium chemistry: Atom-at-a-time gas chromatography studies with polonium

Katharina Hermainski *for the JGU-GSI-HIM-CTU-ÚJF-UiO collaboration*

Collaboration partners

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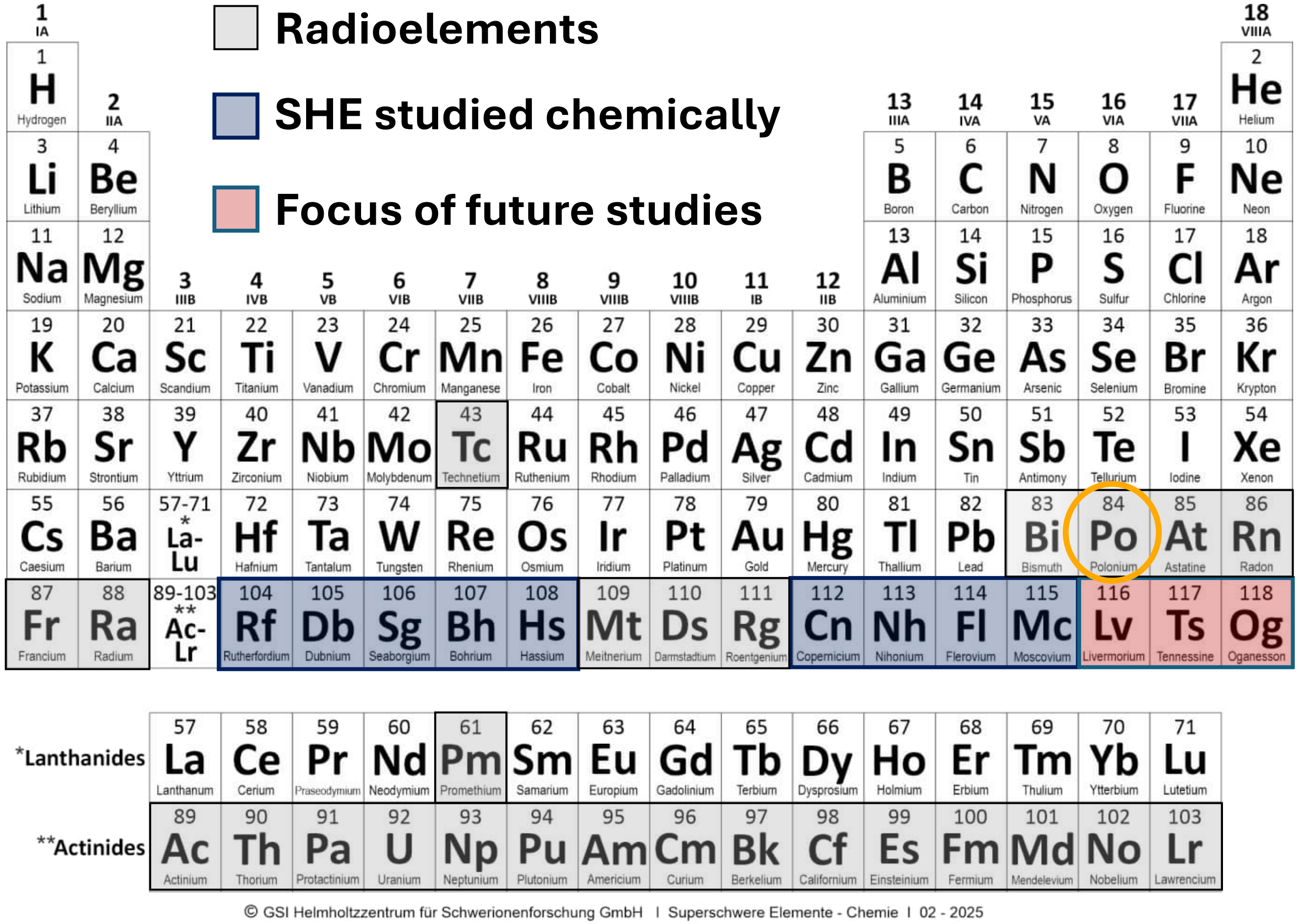
Pushing the heavy element chemistry frontier

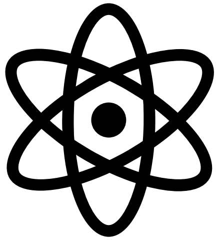


Mc and Nh recently studied chemically

Studying heavier SHE requires...

...Technical developments

➢ Unicell

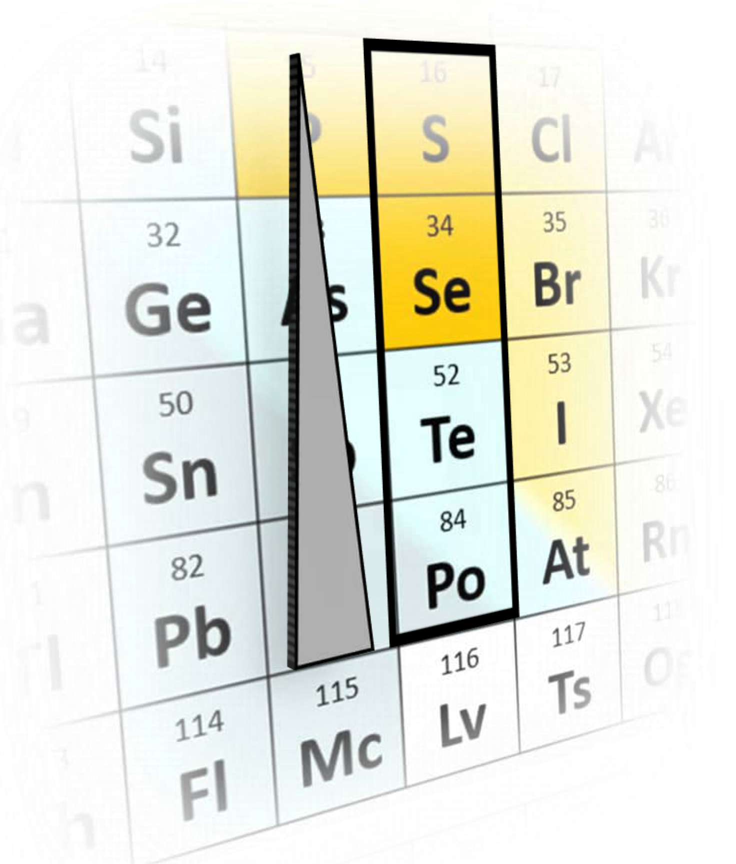


...Studying the chemistry of homologues

➢ Polonium

A. Yakushev et al., *Front. Chem.* **2024**, *12*, 1474820.

What is known about polonium?



Increasing metallic character

Similar compounds as lighter homologues

Oxides

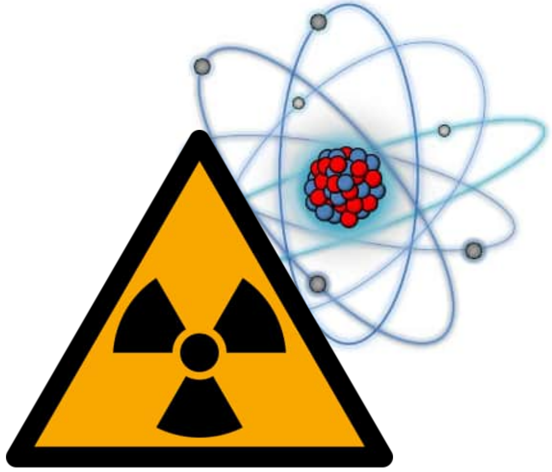
PoO, PoO_2, PoO_3

Oxoacids

$Po(OH)_2$, H_2PoO_3, $PoO_3 \cdot aq$

Halogenides, interchalkogenides, polonides…

Most stable oxidation state: +IV



Highly radiotoxic

What is known about polonium?

Thermochromatography experiments on metals show strong adsorption of polonium to metal surfaces

$-\Delta H_{\mathrm{ads}}^{Au}$ (Po) = (250 ± 7) kJ/mol

E. A. Maugeri et al., *Radiochim. Acta*. **2016**, *104*, 757-767

Similar reactivity of polonium and livermorium predicted in fully relativstic quantumchemical caluclations

V. Pershina, M. Iliaš, *Mol. Phys*. **2025**, *123*, 2573831

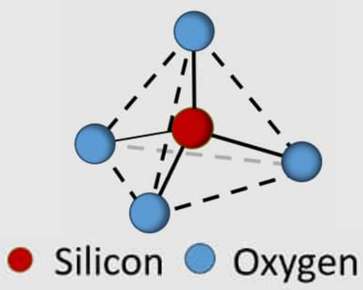
A. Ryzhkov et al., *Phys. Chem. Chem. Phys*. **2023**, *25*, 15362

Experiments with polonium and livermorium on metal surfaces demand high temperatures

Lower temperatures needed on quartz (SiO_2) surfaces

Quartz is the suitable material for future chemical studies of livermorium

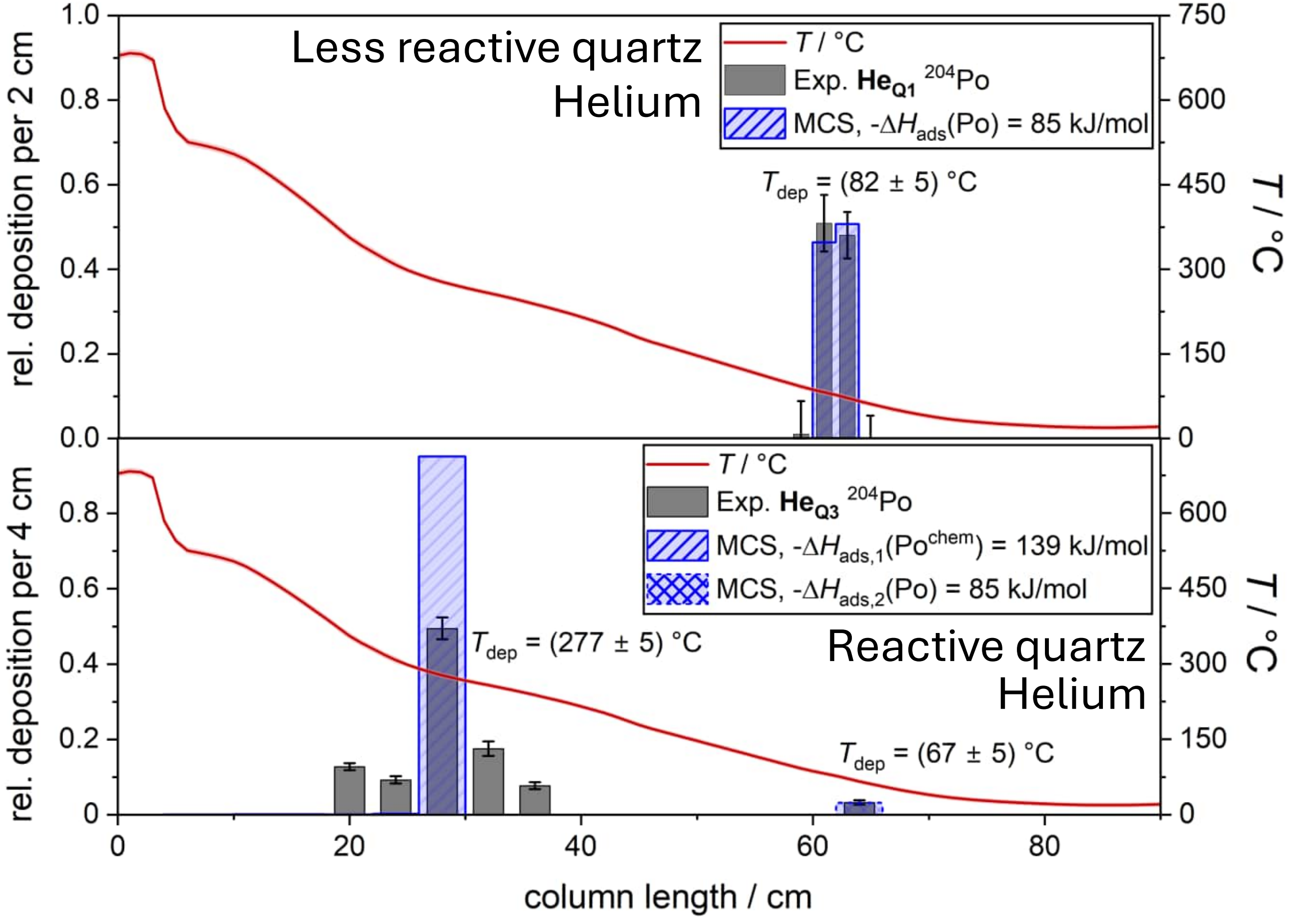
However only one published, detailed adsorption study of polonium on quartz



E. A. Maugeri et al., *J. Nucl. Mater*. **2014**, *450*, 292-298.

Unravelling the influence of the quartz surfaces

Status at TASCA 25: Influence of quartz surface hydroxlation on Po adsorption



Results have been published:

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Unravelling the influence of the quartz surfaces

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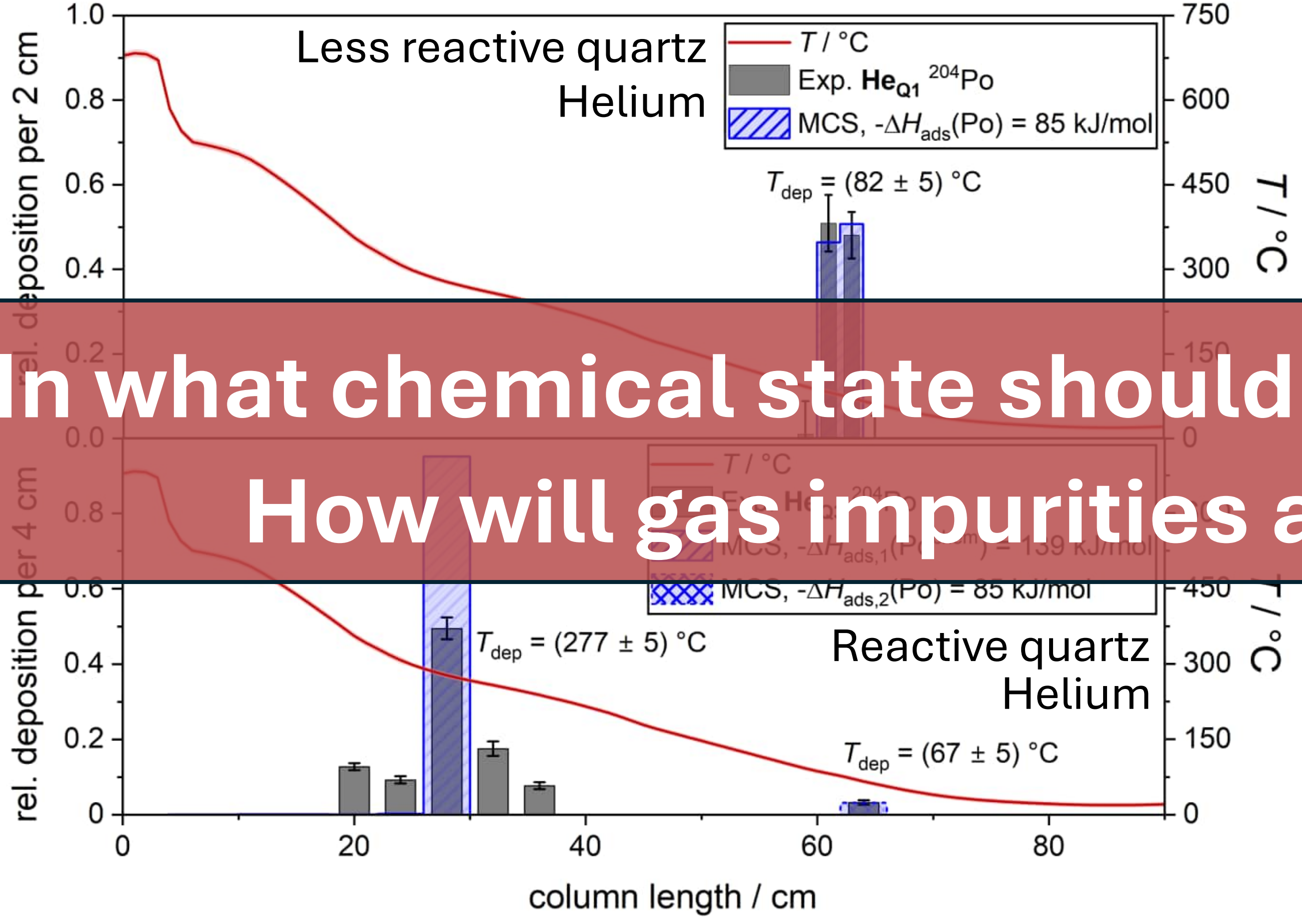


Results have been published:

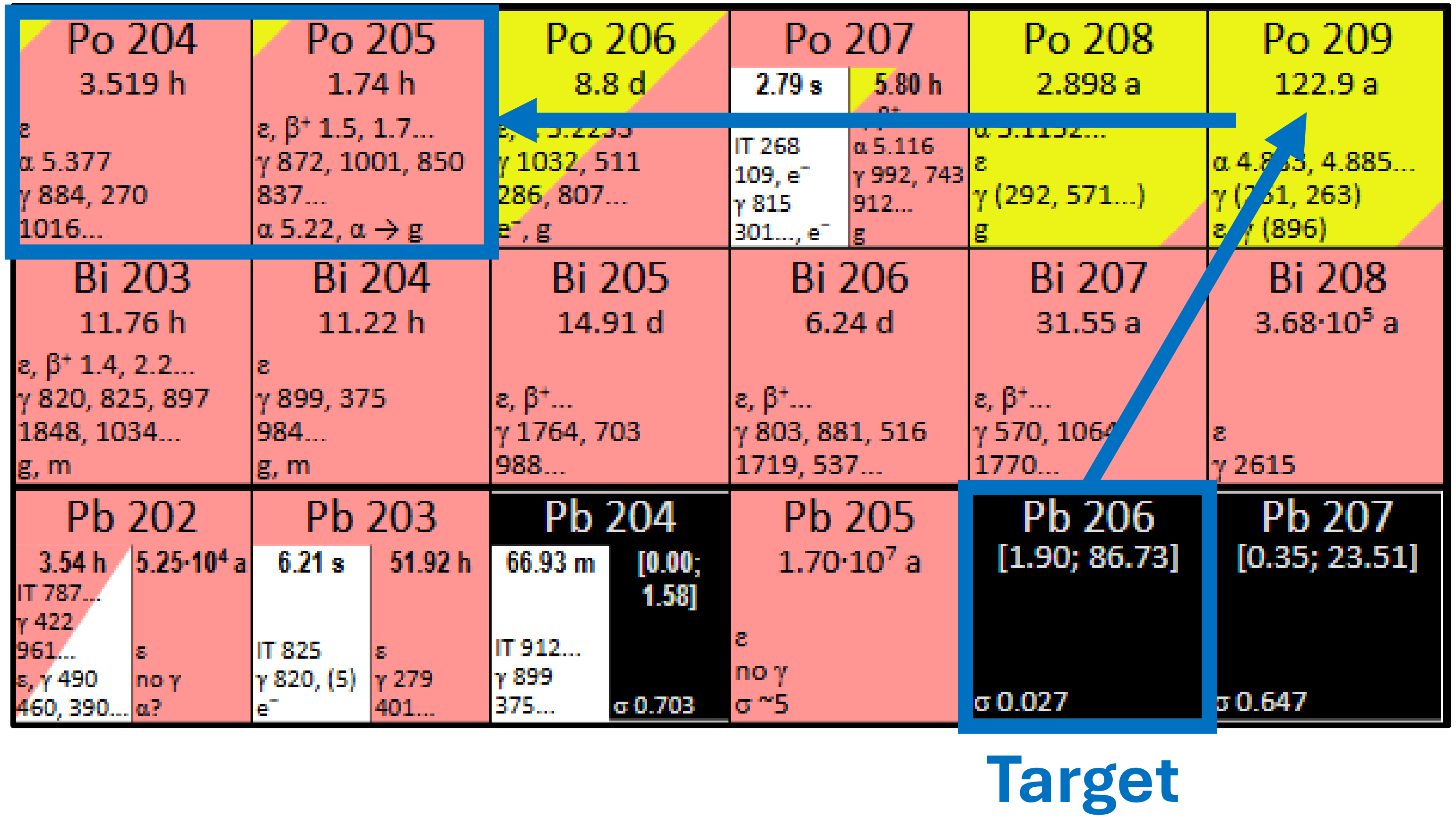
In what chemical state should livermorium be studied?

How will gas impurities affect the experiment?

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Studying Po at the atom-at-a-time regime

Experiments conducted at the Nuclear Physics Institute CAS in Husinec-Řež

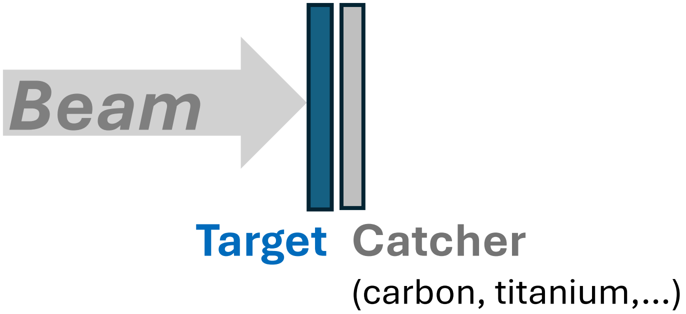


Production in fusion reaction:
$^{206}Pb(^{3}He, 4\text{-}5n)^{205,204}Po$

Beam energy: 48 MeV

Beam current: 200 particle nA

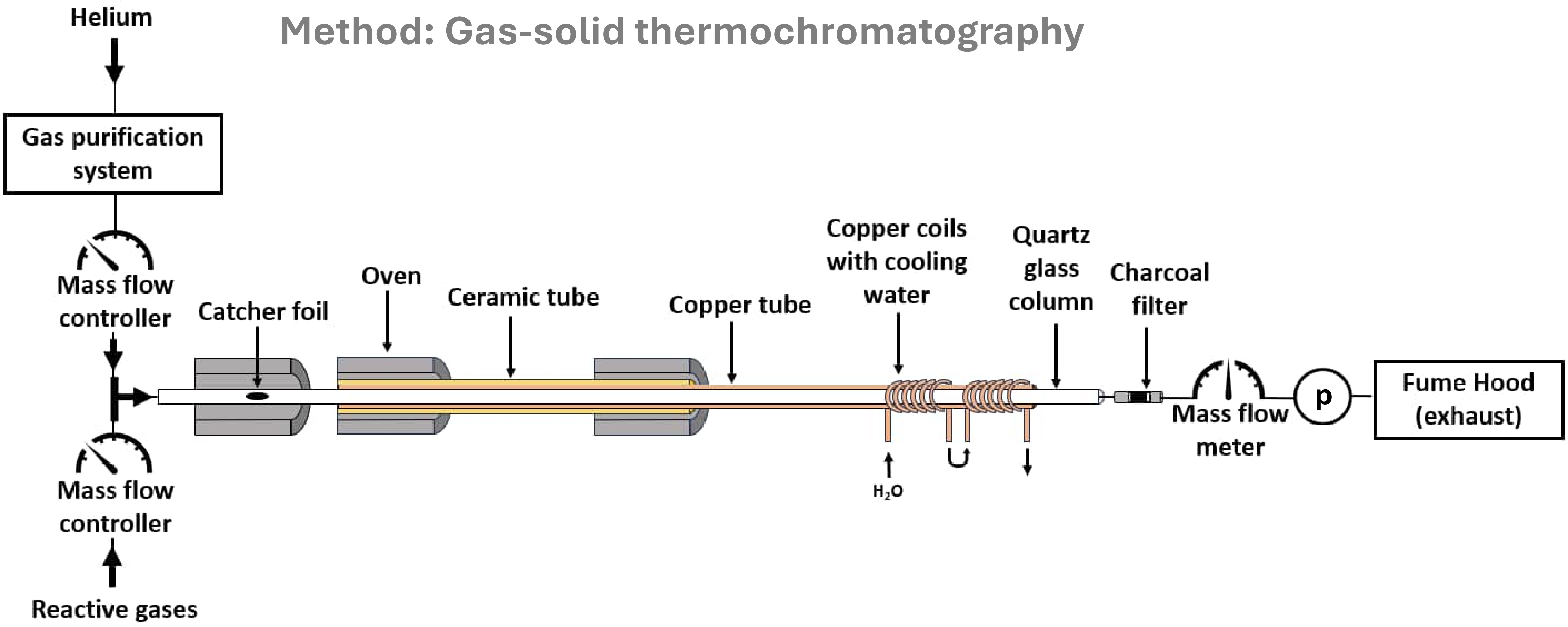
Collection of produced activity in catcher foil (offline experiments)



K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Studying Po at the atom-at-a-time regime

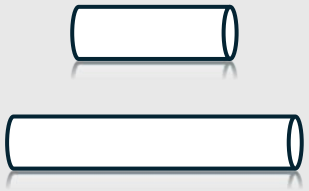
Method: Gas-solid thermochromatography



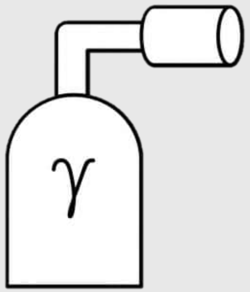
K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Studying Po at the atom-at-a-time regime

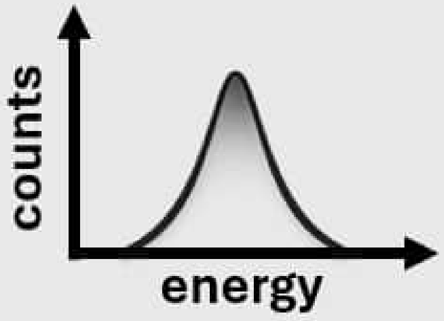
Detection of polonium in the column



Column cut in 2 or 4 cm pieces



γ-Spectra of individual column pieces measured

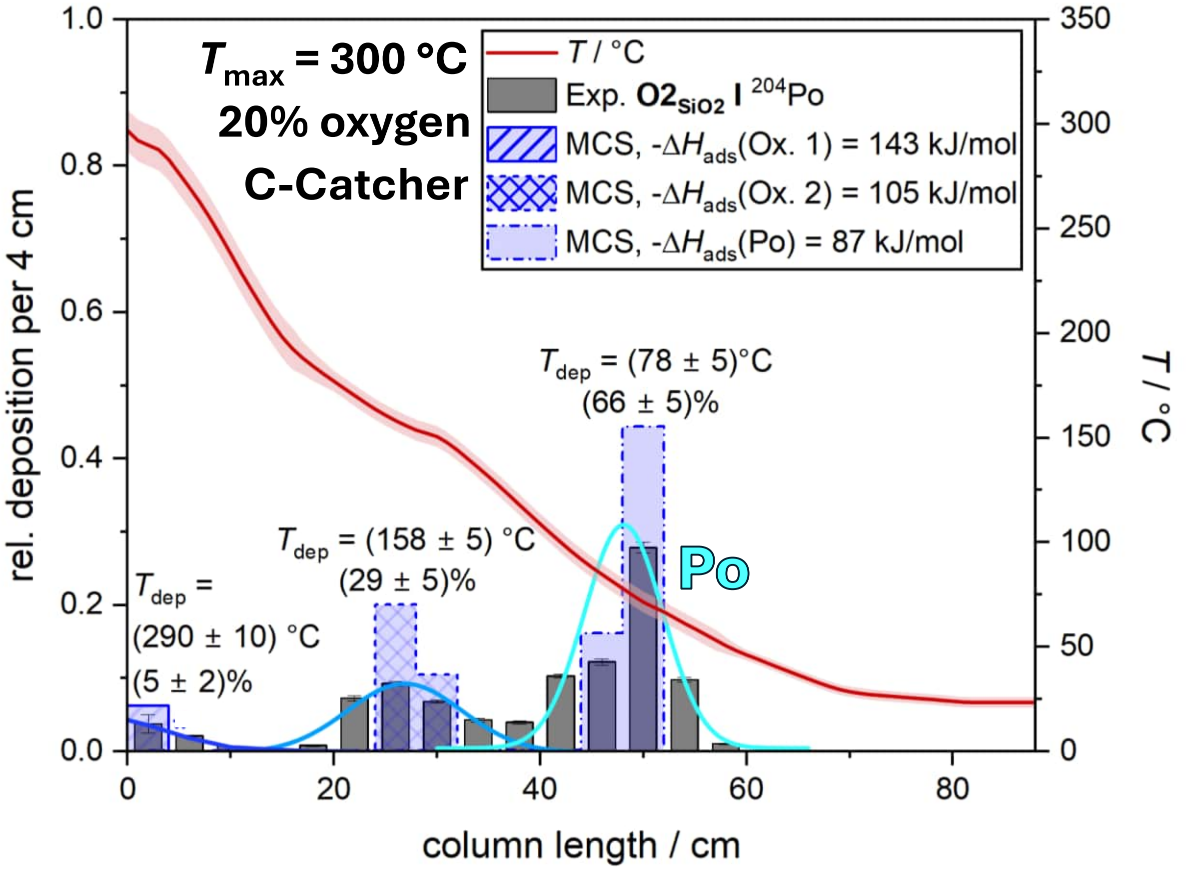


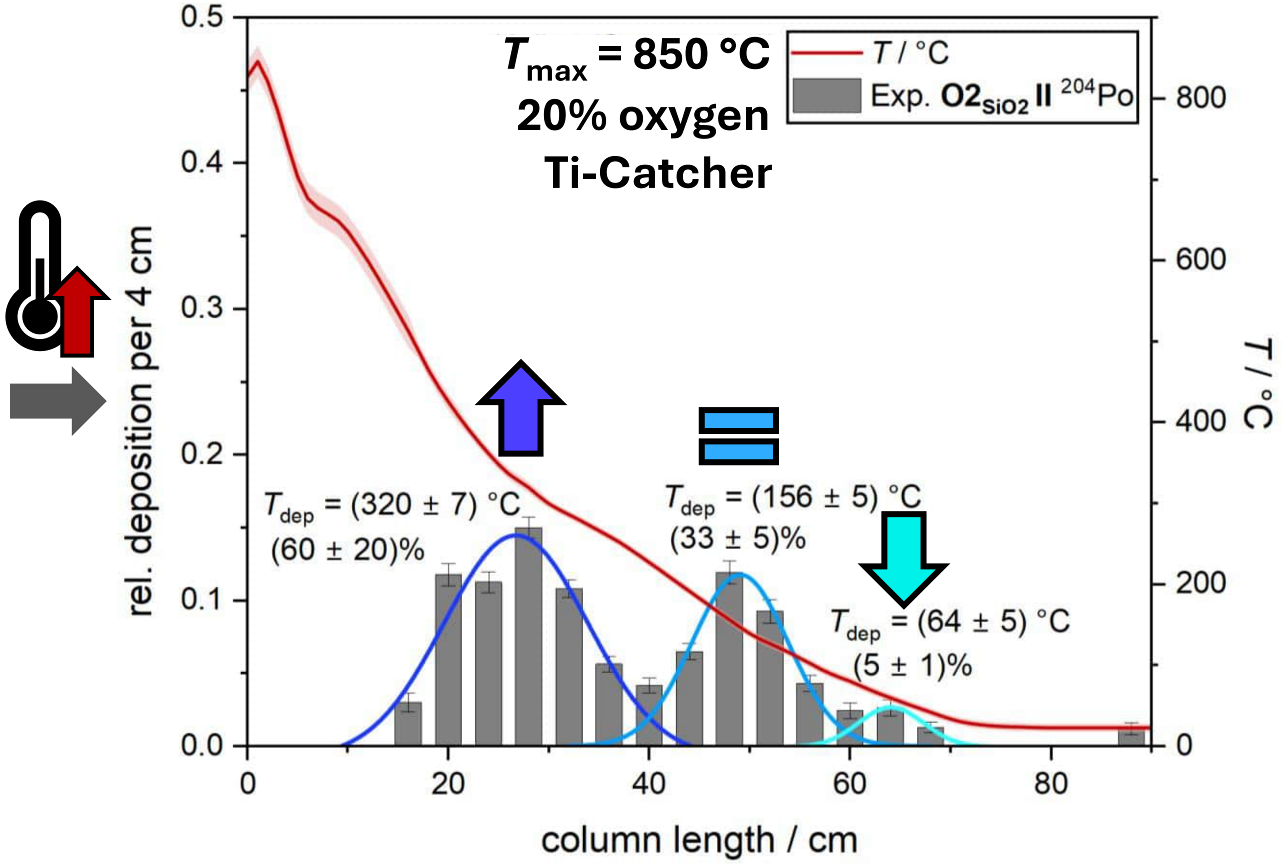
Polonium γ-peaks integrated and baseline- and decay-corrected

Corrected integrals were normalized to total polonium activity

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Reaction of polonium with oxygen



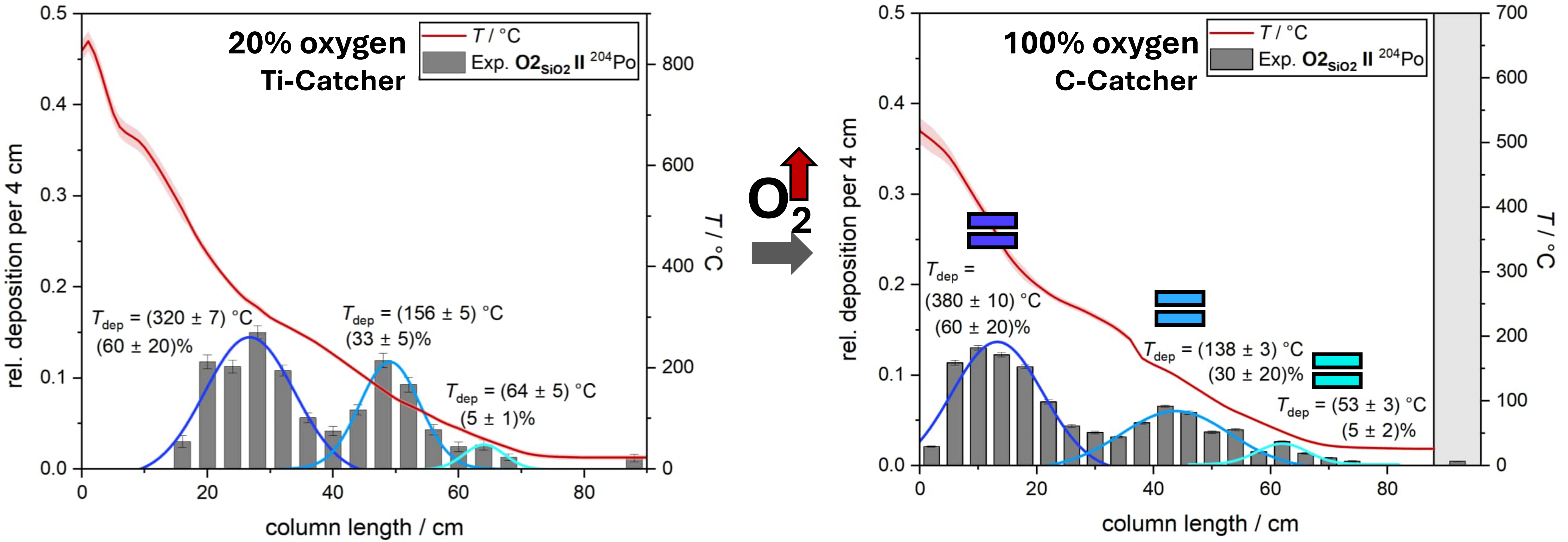


➢ Two oxidized species involved.

➢ Signs of chemical reaction!

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2026**, *28*, 7617-7628.

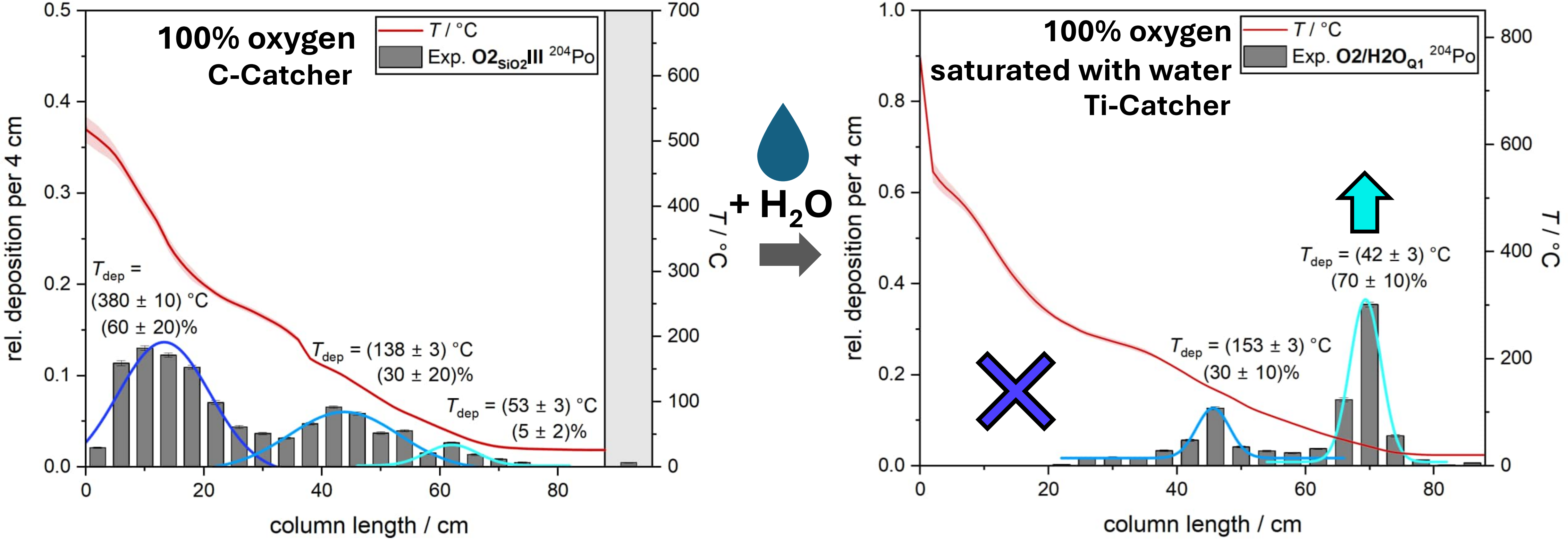
Reaction of polonium with oxygen



➢ Results are reproduced, no change with oxygen content in the gas phase

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2026**, *28*, 7617-7628.

Reaction of polonium with oxygen and water



- ➢ Addition of water significantly effects proceeding chemical reaction.

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2026**, *28*, 7617-7628.

Reaction of polonium with oxygen and water

Two possible explanations:

Volatility: PoO_2 < PoO < Po

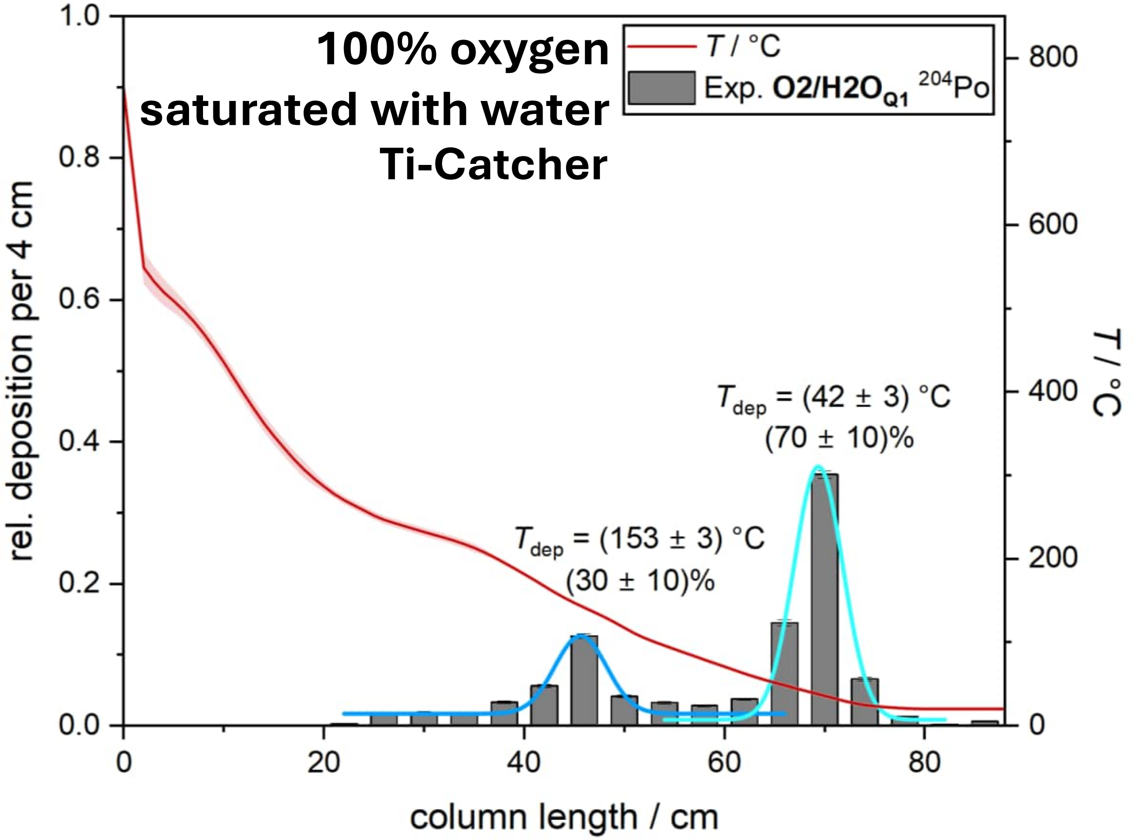
Decomposition of formed oxide species due to *in situ* modification of the surface.

- ➢ In agreement with theory

Volatility: PoO_2 < Oxoacid (H_2PoO_3) < Po

Stepwise reaction: First formation of oxide, then reaction to the more volatile oxyhydroxide.

- ➢ In accordance with Te chemistry



- ➢ Oxidation of polonium in oxygen depends on the maximum temperature and the water content in the carrier gas.

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2026**, *28*, 7617-7628. V. Pershina, M. Iliaš, *Mol. Phys.* **2025**, *123*, 2573831

Summary

- Two oxidizied, less volatile species than elemental polonium are formed in oxygen atmosphere.
- The reaction was found to be dependent on the maximum temperature and the water content in the carrier gas.
- Results can be explained by decomposition of oxides or stepwise reaction with oxygen and water.

Experiments suggest to study livermorium in the elemental state

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2025**, *27*, 21414-21423.

Results presented at TASCA 25, published last year:

Results shown today:

K. Hermainski et al., *Phys. Chem. Chem. Phys.* **2026**, *28*, 7617-7628.

Acknowledgements

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FAIR Phase 0 Research Program

FAIR Czech Republic

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