

## Chemical investigation of hassium (Hs, Z=108)

Ch.E. Düllmann, H.W. Gäggeler, S. Soverna, A. Türler (Univ. Bern & PSI), R. Dressler, B. Eichler, F. Glaus, D.T. Jost, D. Piguet (PSI), T.N. Ginter, K.E. Gregorich, U. Kirbach, D.M. Lee, R. Sudowe, (LBNL), D.C. Hoffman, H. Nitsche, J.B. Patin, P. Zielinski (UC Berkeley & LBNL), W. Brüchle, R. Eichler, E. Jäger, V. Pershina, M. Schädel, B. Schausten, E. Schimpf, H.-J. Schött, G. Wirth (GSI), S.N. Timokhin, A.B. Yakushev (FLNR), K. Eberhardt, P. Thörle, N. Trautmann (Univ. Mainz), Z. Qin (IMP Lanzhou), A. Vahle (FZ Rossendorf)

The heaviest element, whose chemical behavior has been studied so far is bohrium (Bh) with  $Z=107$  [1] behaving like a typical member of group 7 of the periodic table. The longest-lived  $\alpha$ -decaying isotope of the next heavier element hassium (Hs,  $Z=108$ ) is  $^{269}\text{Hs}$  ( $T_{1/2}=11.3$  s) which has been identified in the decay chain of  $^{277}\text{112}$  [2,3]. Hs is supposed to be a member of group 8 of the periodic table and should thus form a very volatile tetroxide. Relativistic density functional calculations predicted the electronic structure of  $\text{HsO}_4$  to be similar to the one of  $\text{OsO}_4$  [4]. Application of different semiempirical models of the interaction of a  $\text{MeO}_4$  molecule with quartz surface predicted the adsorption behavior of  $\text{OsO}_4$  and  $\text{HsO}_4$  to be very similar [4]. Extrapolations of trends within group 8 of the periodic table also predicted  $\text{HsO}_4$  and  $\text{OsO}_4$  to behave similar in a gas adsorption chromatography experiment [5].

Hs isotopes were produced directly in the reaction  $^{248}\text{Cm}(^{26}\text{Mg};5,4n)^{269,270}\text{Hs}$  at the UNILAC at GSI Darmstadt [6]. Hs isotopes recoiling from the target were thermalized and oxidized in a  $\text{He}/\text{O}_2$  mixture in the recoil chamber of the In-situ Volatilization and On-line detection apparatus IVO [7]. Volatile  $\text{HsO}_4$  was transported with the carrier gas to the Cryo-On-Line-Detector (COLD), a thermochromatography device. Along a narrow channel formed of PIN-diodes registering  $\alpha$ -decaying and spontaneously fissioning (SF) nuclides, a temperature gradient from  $-20$  to  $-170$  °C was established. The deposition temperature of volatile species could therefore be determined, allowing for the determination of their adsorption enthalpy. COLD is an improved version of the Cryo-Thermochromatography Separator CTS developed at Berkeley [8].

Five decay chains were detected in the course of the experiment which were attributed to  $^{269}\text{Hs}$  or the so far unknown isotope  $^{270}\text{Hs}$  [6]. In addition, two  $\alpha$ -SF correlations were observed in detectors 3 and 4 that still have a rather low random probability, but could not be assigned with certainty to either  $^{269}\text{Hs}$  or  $^{270}\text{Hs}$  [6]. The deposition temperature of the Hs containing molecules was determined to  $(-44\pm 5)$  °C giving strong evidence of the formation of  $\text{HsO}_4$ . In an irradiation of a  $^{152}\text{Gd}$  target,  $^{172}\text{Os}$  ( $T_{1/2}=19.2$  s) was produced in the reaction  $^{152}\text{Gd}(^{26}\text{Mg};6n)$  and a deposition temperature of  $(-82\pm 5)$  °C was measured for  $^{172}\text{OsO}_4$ . The deposition distribution in the COLD array along the detector pairs is shown in Fig. 1. From these deposition peaks the adsorption enthalpies were deduced applying a Monte-Carlo simulation based on a microscopic description of the transport process in the chromatography column [9], i.e. in the COLD system. Since the half-life of the nuclide is a crucial parameter in this simulation and this value has not yet been measured for  $^{270}\text{Hs}$ , only the three events

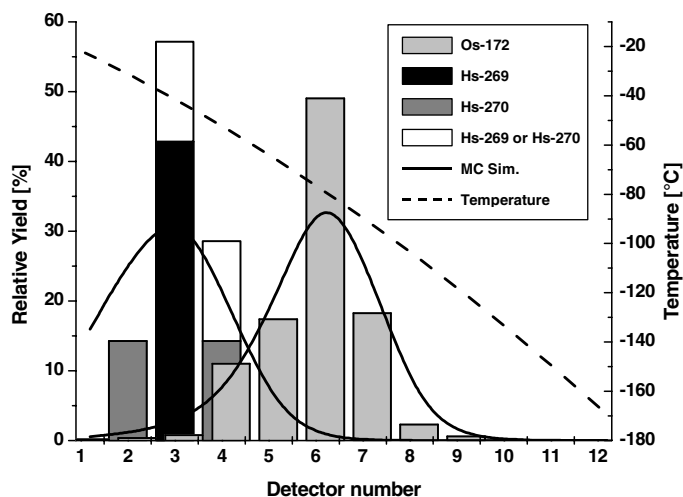


Fig. 1 Merged thermochromatograms of  $\text{OsO}_4$  and  $\text{HsO}_4$ . The solid lines represent results of a Monte-Carlo Simulation with  $\Delta H_{\text{ads}}$  values of  $-39.5$   $\text{kJ}\cdot\text{mol}^{-1}$  ( $\text{OsO}_4$ ) and  $-47$   $\text{kJ}\cdot\text{mol}^{-1}$  ( $\text{HsO}_4$ ), respectively. The dashed line indicates the temperature gradient.

assigned to  $^{269}\text{Hs}$  were used for the simulation.  $\Delta H_{\text{ads}}(\text{HsO}_4)=(-47\pm 2)$   $\text{kJ}\cdot\text{mol}^{-1}$  (68 % c.i.) was evaluated, compared to  $\Delta H_{\text{ads}}(\text{OsO}_4)=(-39.5\pm 1.0)$   $\text{kJ}\cdot\text{mol}^{-1}$ . The latter value is in good agreement with  $\Delta H_{\text{ads}}(\text{OsO}_4)=(-38.0\pm 1.5)$   $\text{kJ}\cdot\text{mol}^{-1}$  evaluated in earlier experiments.

With the formation of a very volatile oxide, presumably  $\text{HsO}_4$ , Hs behaves similar to Os, its next lighter homologue in group 8 of the periodic table.

## References

- [1] R. Eichler et al., *Nature* **407**, 63 (2000).
- [2] S. Hofmann et al., *Z. Phys.* **A354**, 229 (1996).
- [3] S. Hofmann et al., *Rev. Mod. Phys.* **72**, 733 (2000).
- [4] V. Pershina et al., *J. Chem. Phys.* **115**, 792 (2001).
- [5] Ch.E. Düllmann et al., *J. Phys. Chem. A* (submitted)
- [6] A. Türler et al., this Annual Report and submitted to *Phys. Rev. Lett.*
- [7] Ch.E. Düllmann et al., *Nucl. Instrum. Meth.* **A479**, 631 (2002).
- [8] U. Kirbach et al., *Nucl. Instrum. Meth. A* (in press)
- [9] I. Zvara et al., *Radiochim. Acta* **38**, 95 (1985).