Chemistry of Hassium

First Chemical Study of Element 108

An international team of scientists from China, Germany, Russia, Switzerland and the USA succeeded in investigating chemical properties of element hassium with the atomic number Z=108. With only seven identified hassium atoms, the researchers could demonstrate that hassium behaves like a typical member of group 8 (Fe, Ru, Os) of the periodic table.

Six new elements with the atomic numbers 107 to 112 have been synthesized and identified at GSI over the past 20 years. Experimental evidence for the existence of even heavier elements, with atomic numbers 114 and 116, was recently reported from JINR Dubna. While these pioneering experiments add to our knowledge about the stability and properties of the heaviest atomic nuclei, they have not provided information on the chemical behavior of the new elements.

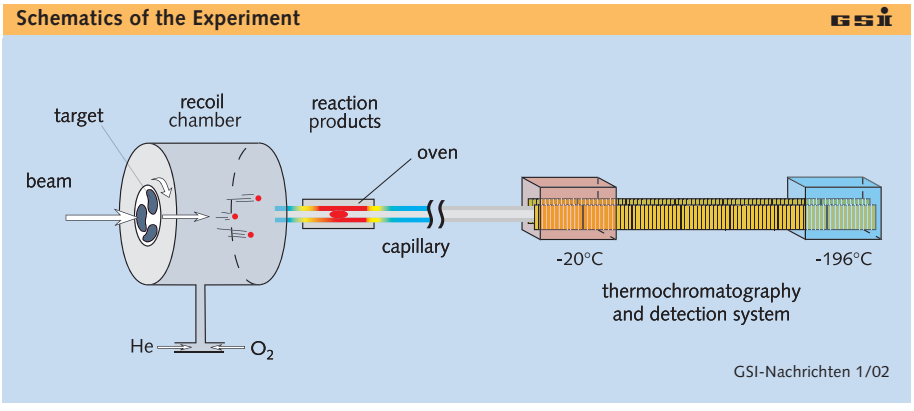
To obtain—with only a few atoms available—information on the chemical properties of an unstable element, requires dedicated experimental set-ups, on the one hand, and longer-lived isotopes with half-lifes in the second region, on the other. The latter is necessary for applying chemical separation techniques. The heaviest element studied so far with gas or liquid chromatography techniques is bohrium, with the atomic number 107. Bohrium behaves like a member of group 7 of the periodic table.

The next heavier element hassium (Hs) is expected to show the properties of a group 8 element. Extrapolating from the typical behavior of the well known homologues Fe, Ru, and Os, it should form a very volatile tetroxide. Relativistic density functional calculations predict the electronic structure of HsO_4 to be similar to that of OsO_4. Consequently, the adsorption behavior of both molecules is expected to be similar.

The research team used the experimental set-up sketched in Figure 1. To probe the chemical properties of Hs, the long-lived isotope ^{269}Hs with a half-life of $T_{1/2} \approx 10$ s was produced via the reaction ^{248}Cm(^{26}Mg, 5n)^{269}Hs [1,2]. The Hs recoils were thermalized in a He/O_2 gas stream and then, in an oven heated to 600°C, converted into HsO_4, which is volatile at room temperature. With the gas flow, the HsO_4 molecules were then transported via a 10 m long teflon capillary to the low temperature thermochromatographic detection system, which registered the nuclear decay (α decay and spontaneous fission) in the hassium decay chain. The detection system consists of an array of 12 pairs of Si detectors. A temperature gradient was established along the detector by cooling its entrance to –20°C and its exit to liquid nitrogen temperature (-196°C). Depending on their volatility, the HsO_4 molecules were expected to adsorb at a position characteristic of a specific adsorption temperature.

In the experiment, seven hassium decay chains were detected, six were attributed to ^{269}Hs and one to the so far unknown isotope ^{270}Hs. The results of the thermochromatography measurements are shown in Figure 2. The deposition temperature of HsO_4 was determined to be –44 ± 6°C. For comparison the deposition temperature of $^{172}OsO_4$ was also measured using the

Figure 1: *Schematic drawing of the set-up used to produce and isolate Hs isotopes in form of the volatile HsO_4. The ^{26}Mg-beam passes through the rotating vacuum window and ^{248}Cm-target assembly. In the fusion reaction, ^{269,270}Hs nuclei are formed, which recoil out of the target into a gas volume flushed with a He/O_2 mixture, and then on a quartz column containing a quartz wool plug which is heated to 600°C. There, Hs is converted to HsO_4, which is volatile at room temperature, and transported with the gas flow through a teflon capillary to a detector array registering the Hs decay chains (α decays and spontaneous fission). The array consists of 12 pairs of Si detectors. A thermostate keeps the entrance of the array at –20°C; the exit is cooled to –196°C by means of liquid nitrogen. Depending on the volatility of HsO_4, the molecules adsorb at a characteristic position.*



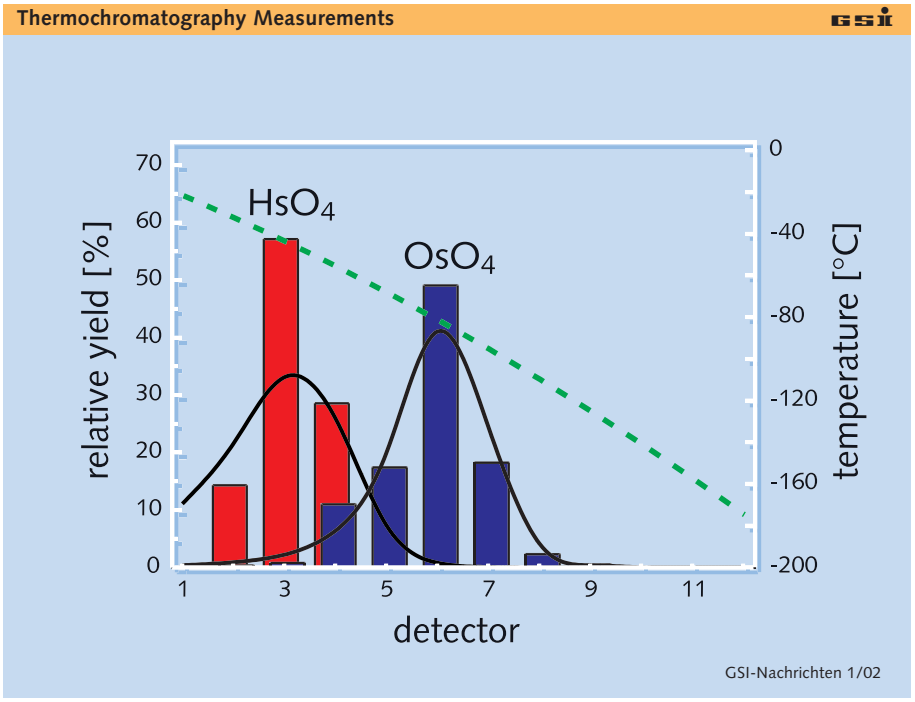


Figure 2: *Thermochromatogram of HsO_4 and OsO_4. Indicated are the relative yields of HsO_4 (red) and OsO_4 (blue) for each of the 12 detector pairs. The green dashed line indicates the temperature profile. The solid lines represent results of a simulation of the adsorption process with standard adsorption enthalpies of ΔH_{ads} = -46 kJ mol^{-1} for HsO_4 and –39 kJ mol^{-1} for OsO_4.*

reaction ^{152}Gd(^{26}Mg, 6n)^{172}Os yielding -82 ± 7°C. By applying Monte Carlo simulations based on microscopic descriptions of the transport process, the adsorption enthalpies were deduced, yielding ΔH_{ads} values of –46 kJ mol^{-1} for HsO_4 and –39 kJ mol^{-1} for OsO_4, respectively.

In summary, the experiments have provided the first information on the chemical behavior of element 108 (Hs). With the formation of a very volatile tetroxide (HsO_4), Hs behaves like a typical member of group 8 of the periodic table. This also confirms the previous assignment of the nuclear charge based on the observed α decay chains.

The Hassium experiments pave the way to chemical studies of still heavier elements. As the next step, the international collaboration aims at the investigation of element 112. Here, one expects a clear cut deviation from the systematics given by the periodic table. Atomic shell calculations, taking into account relativistic effects due to the large nuclear charge of the heavy elements, predict the chemical properties of element 112 to resemble those of noble gases rather than those of its homologue Hg. ■

References

[1] A. Türler et al., submitted to Eur. Phys. J.

[2] C. Düllmann et al., submitted to Nature

Discovery of Element 110 Credited to GSI

Elements 111 and 112 Need Further Experimental Confirmation

A Joint Working Group of the International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Pure and Applied Physics (IUPAP) has credited the discovery of element 110 to GSI. The results on the elements 111 and 112 are evaluated to be of high quality, but of insufficient internal redundancy to fulfill the discovery criteria at the present stage. The abstract of the Technical Report, published by the Joint Working Group in Pure Appl. Chem., Vol. 73, No. 6, pp. 959-967, 2001, reads:

"The IUPAC/IUPAP joint working party on the priority of claims to the discovery of elements 110, 111, and 112 has reviewed the relevant literature pertaining to the several claims. In accordance with the criteria for the discovery of elements, previously established by the 1992 IUPAC/IUPAP Transfermium Working Group, it was determined that the claim by the Hofmann et al. research collaboration for the discovery of element 110 at GSI has fulfilled those criteria. For elements 111 and 112, the collaboration of Hofmann et al. produced high-quality data with plausible interpretations, but confirmation by further results is needed to assign priority of discovery for these elements. The working party was not convinced that claims of other collaborations have satisfied the discovery criteria."

Subsequent to the IUPAC/IUPAP report three experiments have been performed at GSI in which three additional decay chains for element 111 and one additional chain for element 112 were observed, confirming the previous discovery. ■