Online chemical study of Pb, Hg and Tl on SiO_2 and Au surfaces at TASCA

L. Lens[1], J. Ballof[1], A. Yakushev[2], Ch.E. Düllmann[1,2,3], H. Brand[2], X. Derkx[1], A. Di Nitto[1], J. Even[3], W. Hartmann[2], F.P. Heßberger[2,3] A. Hübner[2], E. Jäger[2], J. Khuyagbaatar[2,3], B. Kindler[2], J.V. Kratz[1], J. Krier[2], N. Kurz[2], B. Lommel[2], C. Mokry[1], J. Runke[2], P. Scharrer[3], B. Schausten[2], J. Steiner[2], P. Thörle-Pospiech[1,3], M. Wegrzecki[4], N. Wiehl[1,3], V. Yakusheva[3]

[1]Univ. Mainz, Germany; [2]GSI, Darmstadt, Germany; [3]Helmholtz Institut Mainz, Germany; [4]ITE, Warsaw, Poland

Experiments on the interaction of lead (Pb), mercury (Hg), and thallium (Tl) with SiO_2 and Au surfaces were conducted at the gas-filled separator TASCA as preparatory experiments for future studies of the chemistry of element 113 and Fl (flerovium, Z=114).

A first experiment, with Hg focused on the minimization of the transport time for short-lived radionuclides to the gas chromatography setup COMPACT [1]. This is crucial for successful experiments with superheavy elements, due to their low production rates and short half-lives. The complete fusion reaction (188 MeV) $^{40}Ar+^{144}Sm$ (415 µg/cm^2, ^{144}Sm as SmF_3) was applied to produce Hg, using short (1 s) beam pulses, repeated every 60 s. Hg was separated from unwanted reaction products by the magnetic recoil separator TASCA. In the TASCA focal plane, Hg penetrated a thin Mylar^R window and entered the Recoil Transfer Chamber (RTC) [2], which was connected to the gas transport system and constantly flushed by a He/Ar (70/30) mixture with a flow rate between 0.7-0.85 l/min. A 4 m Teflon capillary (1 mm inner diameter) connected the RTC (volume: 140x40x20 mm^3)) to COMPACT, which was kept at room temperature. The thin capillary led to a reduced pressure in COMPACT, beneficial for getting good energy resolution. The surface of the detector array was covered with a thin gold layer. The carrier gas, purified by Hydrosorb^{TM} and Oxisorb^{TM} cartridges, was circulated in a loop. A mean transport time of 3.6 ± 0.3 s was determined. To reduce this, a Teflon insert inside the RTC (RTC dimensions: 70x40x20 mm^3) was installed and the capillary between RTC and COMPACT was changed to a 20 cm capillary (inner diameter: 1 mm), so the gas flow rate could be increased to 1.7 l/min. Due to these changes, the mean transport time was reduced to 1.5 ± 0.5 s. To avoid losses of reaction products in the RTC, denser carrier gas (e.g., Ar instead of He/Ar) could now be used.

In a second experiment, the adsorption behavior on SiO_2 and Au surfaces of the rather reactive metal Pb was directly compared to that of the less reactive metal Hg, as well as to that of Tl, which is a chemical homolog of element 113. For this, two COMPACT arrays, both kept at room temperature, were connected in series (COMPACT^2). The detectors of the first one were covered with a SiO_2 layer and those of the second one by Au. Previous work showed that Pb should be retained on SiO_2 at temperatures below 600 °C, while Hg can be adsorbed at room temperature on Au, but not on SiO_2 [3-6]. The reactions of 300.8 MeV ^{50}Ti with ^{140}Ce, ^{141}Pr, and ^{142}Nd (400µg/cm^2, present as trifluorides) were used to produce $^{182-184}Hg$, $^{184,185}Tl$, and $^{185,186}Pb$. Mercury was detected in COMPACT by irradiations of all three targets, produced as a fusion product from different de-excitation channels, or as decay product after α or EC/β^+-decays from Pb or Tl, respectively. Pure Ar was used as carrier gas, which allowed reduction of the RTC depth, but negatively affected the energy resolution. Additionally to Hydrosorb^{TM} and Oxisorb^{TM} cartridges, a hot Ti getter was installed for further reduction of the O_2, H_2O content. As shown in Fig. 1 (upper panel), the separation of Pb and Hg based on their different reactivity towards SiO_2 was achieved.

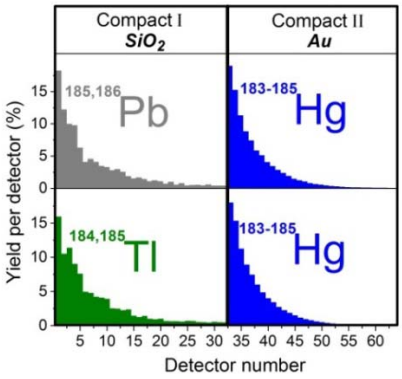

Figure 1: Pb, Tl and Hg distributions in COMPACT^2

Pb was retained under diffusion-controlled deposition in the first COMPACT array, whereas Hg passed this and deposited on the Au surface. The obtained results agree with theoretical predictions [3,7] and helped optimizing the experimental setup for an upcoming Fl experiment. This improved setup allows to directly compare the chemical behavior of Fl, Pb, Hg, Cn and Rn.

For the first time, Tl was investigated in the online regime. Short-lived Tl radioisotopes were pre-separated with TASCA, thermalized in the RTC and carried by Ar gas further to COMPACT, cf. Fig. 1 (lower panel). They adsorbed on the SiO_2 coated detector array, which agrees with offline studies on SiO_2 and Au surfaces [8]. Produced Hg isotopes were detected on the Au surface of the second COMPACT array.

References

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