Production of radionuclides for online chemistry experiments

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The heavy elements group conducted two experiments during the past year related to producing short-lived radionuclides for online chemistry experiments. The first experiment produced activity that was delivered to the Cryo-Online Multidetector for Physics And Chemistry of Transactinides (COMPACT) device developed at the GSI Helmholtzzentrum für Schwerionenforschung (Darmstadt, Germany) [1]. COMPACT was used in a configuration where a gas cell (also developed at GSI) was used to thermalize ions and extract them into COMPACT using an RF funnel. Such a setup would minimize the extraction time of the ions, which will be important in future studies of very short-lived species. This is a natural extension of our previous work, which showed that pre-separation of activity for delivery to a "recoil transfer chamber" (gas cell) is feasible [2]. The COMPACT Si detectors were covered in a thin layer of Au, and three different elements ($^{182\text{-}183}$Hg, ^{187}Pb, and ^{199}At) were used to test the feasibility of such a setup. The second experiment was a proof-of principle for production of ^{184}Tl (10 s, ~2% α branch), which is expected to be a homolog of nihonium (element 113). In both experiments, beams were accelerated by the K500 cyclotron and delivered to the MARS beamline. MARS acted as a pre-separator [3], and purified beams were delivered to either COMPACT in the first experiment or a position-sensitive strip detector in the second experiment. Table I summarizes the irradiations and Fig. 1 shows the gas cell and COMPACT installed on MARS. Preliminary results are reported here.

Table 1. Summary of irradiations related to production of short-lived radionuclides for chemistry experiments.

Date	Primary Reactions	Detection System
May 2017	^{144,147}Sm(^{40}Ar, xn)$^{182\text{-}183}$Hg ^{152}Gd(^{40}Ar, 5n)^{187}Pb ^{165}Ho(^{40}Ar, 6n)^{199}At	COMPACT
March 2018	^{152}Gd(^{35}Cl, 3n)^{184}Tl ^{103}Rh(^{84}Kr, 3n)^{184}Tl	Si Strip Detector

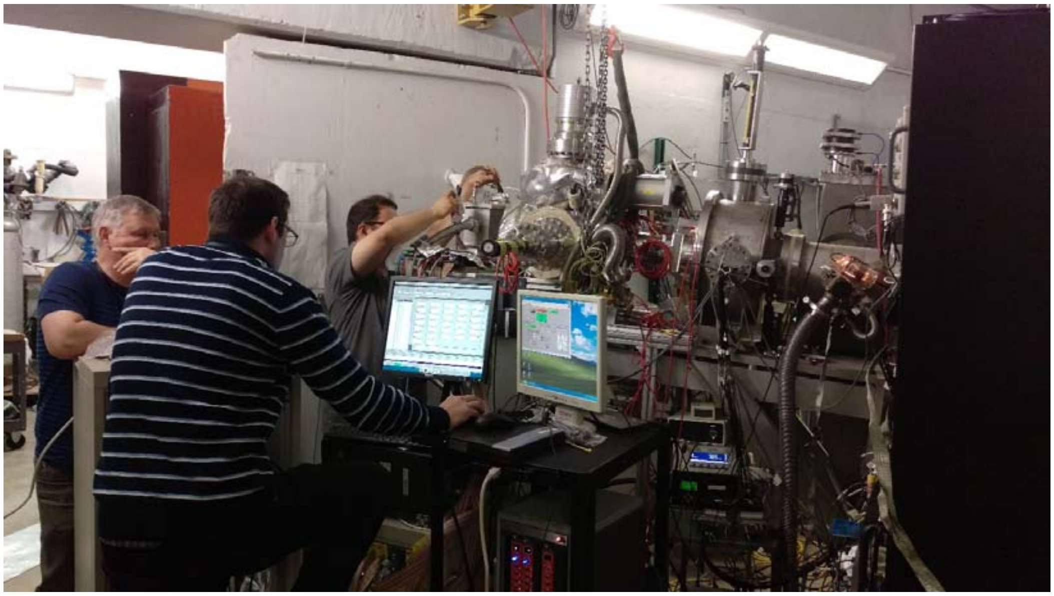

FIG. 1. The gas cell and COMPACT mounted on the detection chamber of MARS.

The COMPACT experiment was successful, as $^{180,182\text{-}183}$Hg were detected due to adsorption on the Au-coated Si detectors. A significant yield of ^{199}At was also observed, as was a very small yield of ^{187}Pb. The primary goal of demonstrating that a gas cell with an RF funnel can be used to provide fast extraction of activity to COMPACT was achieved.

The second experiment tested the feasibility of producing ^{184}Tl using the ^{152}Gd(^{35}Cl, 3n) and ^{103}Rh(^{84}Kr, 3n) reactions. The ^{35}Cl-based reaction may have produced ^{184}Tl, but the magnetic rigidity of the primary beam was similar to that expected for the products, and a high rate of background was

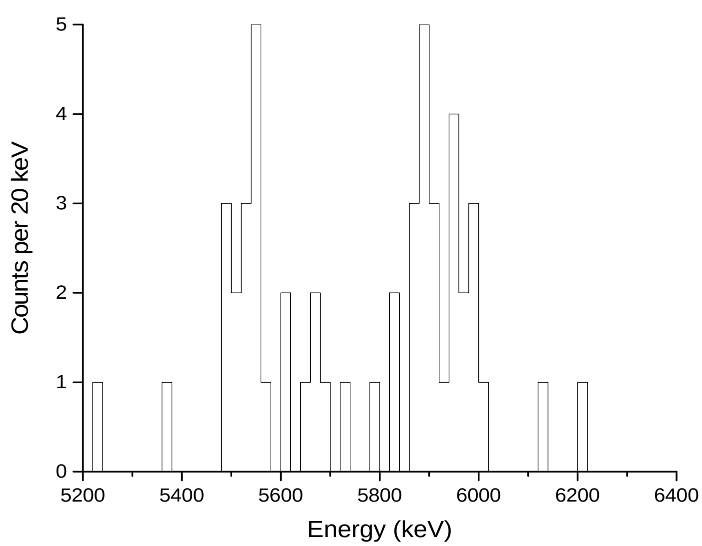

FIG. 2. Alpha spectrum observed at the focal plane detector in the reaction ^{84}Kr + ^{103}Rh. The peak near 5.50 × 10^{3} keV is assigned to ^{184}Hg and the peak just below 6.00 × 10^{3} keV is assigned to ^{184}Tl based on a preliminary calibration. These data represent approximately 1 h of irradiation.

observed. However, the ^{84}Kr-based reaction was successful, and a sample alpha spectrum is shown in Fig. 2. Due to the small alpha branch of ^{184}Tl, only small numbers of counts were observed. In order to make a future chemical experiment feasible, an alpha count rate of ≈1 min^{-1} is needed. The actual observed rate was ≈0.3 min^{-1}, suggesting that relatively modest improvements could make such an experiment feasible. The analysis of these data is ongoing.

In total, these experiments show the feasibility of conducting online chemistry experiments at the Cyclotron Institute.

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