PIGE (Particle Induced Gamma Ray Emission) standards testing

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Particle Induced Gamma Ray Emission (PIGE) is an Ion Beam Analysis (IBA) technique used to study a composition of a sample. This technique allows for multi-elemental, quick analysis, and minimal sample preparation [1]. PIGE has been implemented at Texas A&M University's Cyclotron Institute.

A target nucleus is excited with an ion beam and upon de-excitation characteristic gamma-rays are emitted. PIGE is used for low Z elements, from lithium to aluminum. The PIGE technique has been used to identify per- and polyfluoroalkyl substances (PFAS). PFAS are a group of man-made chemicals found in consumer products that are nonstick, grease- and water-resistant, and in personal care products such as cosmetics [2]. PFAS are of interest since studies have shown these chemicals are linked to health and environmental concerns [2].

During the November 2018 run, it has been observed that the irradiation degrades the standards, lowering the fluorine concentration over time and making them unusable. We thus started the project of making our own standards [3]. Several batches of standards, made over the past few semesters, have been tested in March 2020 and were used to generate a calibration curve. These standards, made at CVE lab building, were prepared with PFOA (perfluorooctanoic acid) with successive dilutions of methanol and water. The standards were dyed with food coloring and pipetted onto a piece of filter paper. The standards have a range of concentrations from 0 – 12k ppm of F (fluorine). The K150 cyclotron was used to bombard the standards with a 3.6 MeV proton beam. The gamma-rays were detected by a CdTe detector which was placed about 45° from the direction of the beam. The decay of ^{19}F nucleus has two characteristic gamma-rays, 110 keV and 197 keV. The total amount of F counts in the two peaks were integrated and normalized. Fig. 1 shows the calibration curve for the organic standards tested during the run. The purpose of this curve is to be used to determine the concentration of fluorine in consumer products.

The F concentrations in standards that were tested during this run need a correction factor for the current that was measured with the Faraday cup (FC). The FC was moved into the beam path for beam current measurements between each run and removed by a stepper motor before the run to prevent background counts from the FC material. To make precise beam intensity measurements an electron suppression negative voltage needs to be applied to the front ring of the cup to repeal back the electrons kicked off by the beam inside the FC but in our case, this voltage was generating a high negative current at the reading output instead of the low positive current that we were expecting. It is hypothesized that the fast electrons coming from the window and the air most likely induced a high negative current when the suppression voltage was applied. Without the voltage, the kicked off electron from the FC were not repealed back in the cup and were thus most likely compensating for the extra fast electrons from the window, providing a more or less correct positive current readout. To test if this hypothesis is correct, a measurement would need to be taken with the same beam, H+, with the cup inside the chamber under vacuum so the electron suppression voltage can be applied efficiently without the contribution of external fast electrons. Another measurement would then need to be taken where the FC originally was during the run (behind the target). With those two measurements, a correction factor can be calculated, which then

can be applied to the current measurements that was read during the run, allowing us to extract more accurate concentration values.

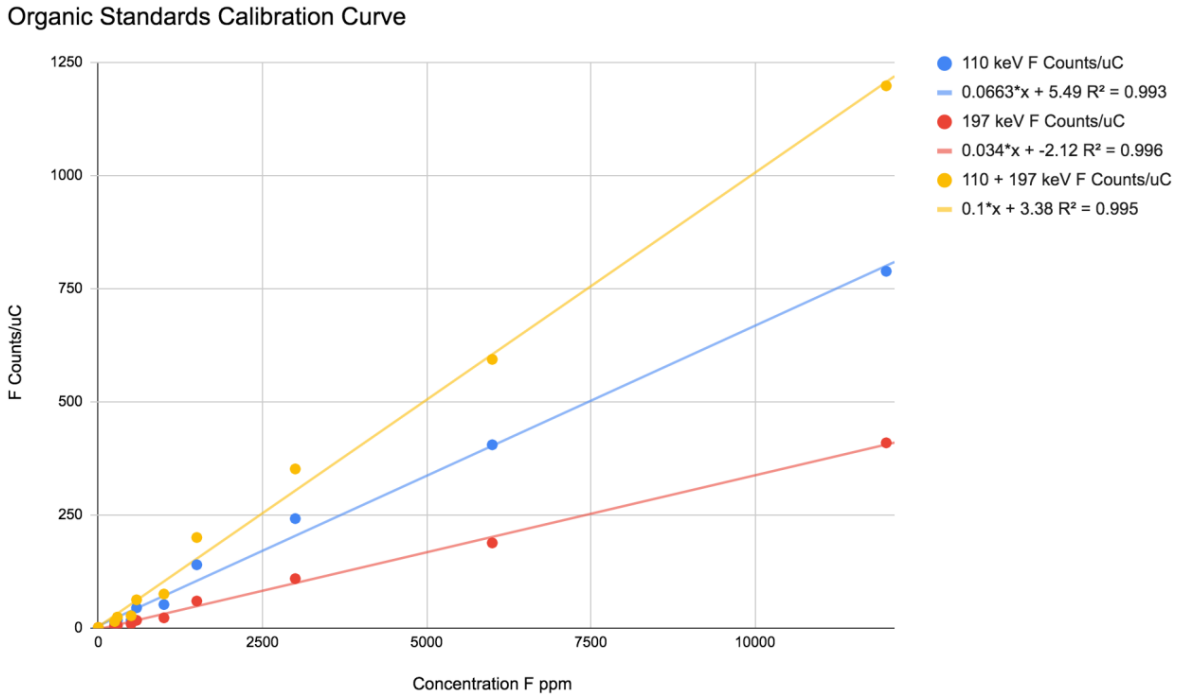

Fig. 1. Organic Standards Calibration Curve with standards ranging from 0 -12k ppm of F.

[1] A. Rodriguez Manso *et al.*, AIP Conference Proceedings **2160**, 050023 (2019).

[2] Laurel A. Schaider *et al.*, Environ. Sci. Technol. Lett., **4(3)**, 105 (2017).

[3] M. McCarthy *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2018-2019), p. IV-61.