Development of a System to Screen for PFAS Chemicals Using PIGE at Union College

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Introduction

Per- and polyfluoroalkyl substances (PFAS) are man-made chemicals that have become a major environmental concern[1]. They can be found in a broad range of products including food packaging, stain- and water-repellent fabrics, nonstick products, makeup, fire-fighting foams, and electronics. PFAS pose a significant risk to the public due to their adverse health effects[2,3]. In addition to this, they are persistent, bioaccumulate, and do not break down in the environment. We aim to employ proton induced gamma ray emission (PIGE) to screen for these hazardous chemicals within our samples. By using PIGE, we are able to clearly see the fluorine peaks, a key identifier of PFAS, within our spectra. Furthermore, PIGE is a powerful technique that is quick and efficient as well as non-destructive. While this analysis method has been developed at other research institutes across the country[2], it is our goal to develop it at Union College so we can begin screening potential hazardous sources of PFAS.

PIGE

Proton induced gamma-ray emission works by bombarding a sample with a beam of protons produced in an accelerator[4]. As the protons penetrate the sample, there are instances where the protons inelastically collide with a nucleus leaving it an excited state. When the nucleus de-excites it releases a gamma-ray which can be detected. The energy of the gamma ray identifies the element and the intensity of gamma-rays at a particular energy can be used to determine the concentration of the element. The PIGE process is illustrated in Figure 1.

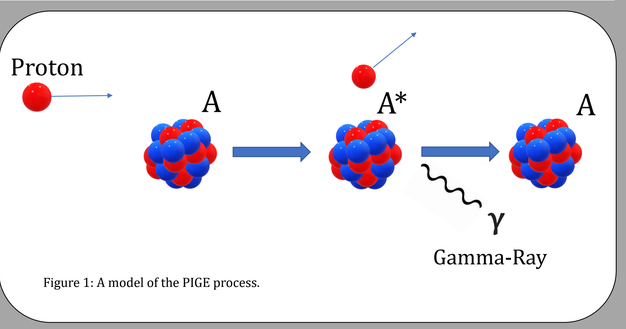

Figure 1: A model of the PIGE process.

Experimental Method

At the Union College Ion-Beam Analysis Laboratory (UCIBAL), we use a 1.1-MV Tandem Pelletron accelerator to accelerate protons up to energies of 2.2 MeV in vacuum. In our setup, we used an external beam facility to bring the proton beam out into the air before colliding with the target. As shown in Figure 2, the sample was placed about 2 centimeters away from the end of the beam pipe at a 45-degree angle relative to the beam. Then we placed our Canberra Ge detector under the sample at 90 degrees relative to the proton beam. In this process, we calculated that the beam lost energy equal to 0.4 MeV as a result of having to pass through the Kapton foil and the 2 centimeters of air. This means that the incident energy on target was 1.8 MeV with an incident current of about 15 nA. Our data were collected over a span of 5 minutes.

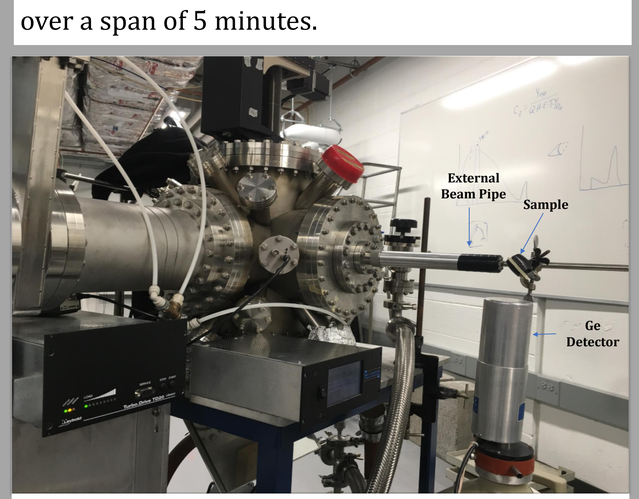

Figure 2: A photograph of our experimental setup with the external beampipe allowing the protons to collide with the target in the air. Also pictured is the Ge detector used to detect the Gamma Rays.

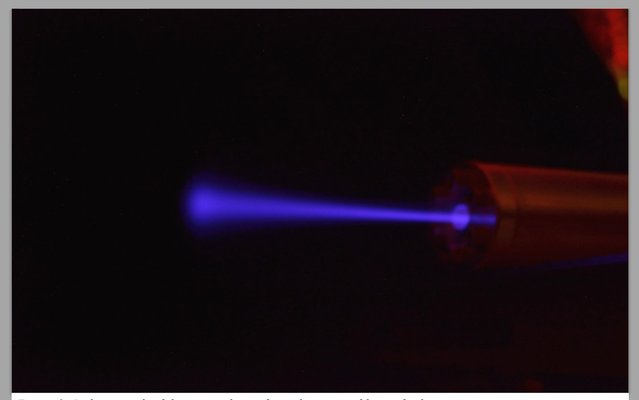

Figure 3: A photograph of the proton beam from the external beam facility.

Qualitative Screening

So far, we have worked on qualitatively screening samples over 5-minute intervals to determine if they contain fluorine. Some of the more notable samples that we found to contain fluorine are Maybelline Color Tattoo Eyeshadow, Oral-B Glide Floss, and McDonald's small fry bag. As shown in Figures 4, 5, and 6, the spectra taken clearly show the presence of fluorine and suggest that the products may contain some form of PFAS. This makes sense since all three of these products are designed to be nonstick, smooth, and water repellent. Overall, this is of great concern since all three of the products are everyday items that come in direct contact with our own bodies. In addition to this, once these items are thrown away, the PFAS can leach out of them and pollute the environment[5]. This may be a reason why we see fluorine in a soil sample taken from Astoria Park along the East River in Queens, New York, seen in Figure 7.

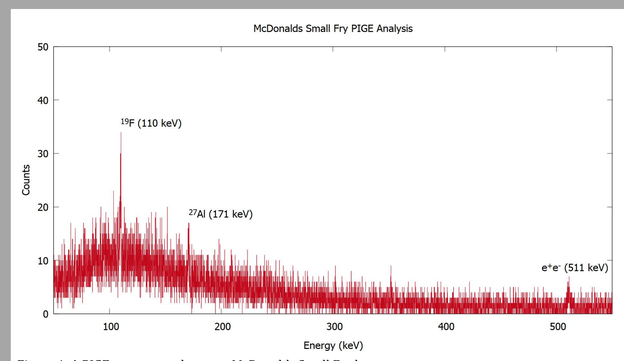

Figure 4: A PIGE spectrum taken on a McDonalds Small Fry bag.

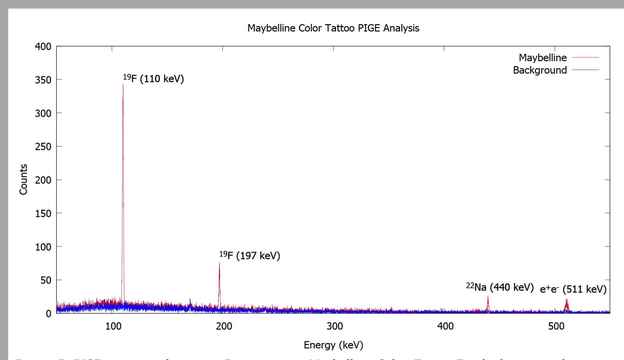

Figure 5: PIGE spectra taken over 5 minutes on Maybelline Color Tattoo Eyeshadow spread across a notecard (Red) and a blank notecard (Blue)

Future Work

In the future we will create fluorinated standards in order to develop a quantitative analysis method for measuring the concentration of fluorine within our samples of interest. This would allow us to use PIGE as a quick screening tool to determine which samples have potentially hazardous levels of PFAS.

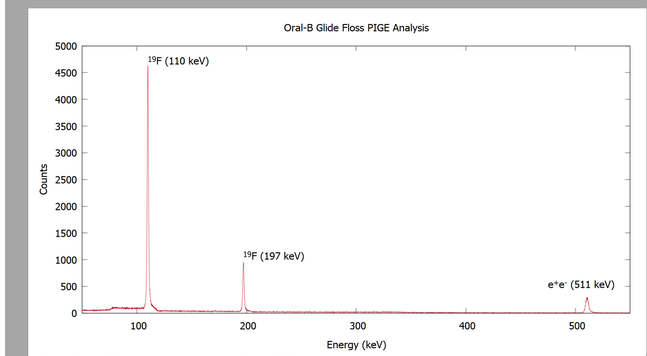

Figure 6: A PIGE spectrum taken on Oral-B Glide Floss.

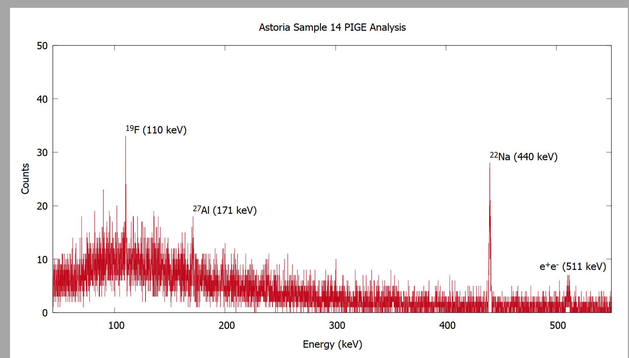

Figure 7: A PIGE spectrum taken on a soil sample from Astoria Park along the East River in Queens, New York.

References

[1] See for example: Turkewitz, Julie. Toxic 'Forever Chemicals' in Drinking Water Leave Military Families Reeling. The New York Times, 2019

[2] Evelyn E. Ritter, et al., "PIGE as a screening tool for Per- and polyfluorinated substances in papers and textiles," Nuclear Instruments and Methods in Physics Research B 407 (2017) 47–54.

[3] Basic Information on PFAS, EPA.gov, 2019

[4] Development of a Reference Database for Particle Induced Gamma Ray Emission (PIGE) Spectroscopy, International Atomic Energy Agency, IAEA-TECDOC-1822, Vienna (2017).

[5] Youn Jeong Choi, Rooney Kim Lazcano, Peyman Yousefi, Heather Trim, and Linda S. Lee, Perfluoroalkyl Acid Characterization in U.S. Municipal Organic Solid Waste Composts Environmental Science & Technology Letters 2019 *6* (6), 372-377DOI: 10.1021/acs.estlett.9b00280

Acknowledgments

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