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Development of a Consistent Proton Induced Gamma Emission Liquid 19F Standard

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Development of a Consistent Proton Induced γ Emission Liquid ^{19}F Standard

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PIGE Spectrum

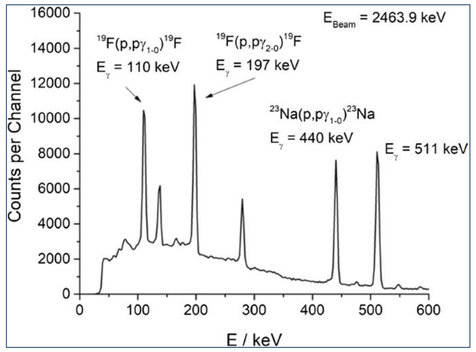

Figure 1. Graph of $^{19}F(p, p'\gamma)^{19}F$ emissions from Fluorine Depth Profiling Article. [1]

Motivation

Polyfluoroalkyl or PFAS, a waterproofing and flame-retardant chemical, is a common industrial water contaminant in Michigan. If PFAS is consumed, it damages the body because the body cannot efficiently excrete it. Associated conditions include: cancer, osteoporosis, muscular and nerve damage, and more. This is why developing a technique to quantify PFAS contamination in water is vital. Drinking water standards of 16 ppt, or parts per trillion, of PFAS were adopted in Michigan in 2020 [2]. As such, it was necessary to develop a technique for testing PFAS at these levels.

Abstract

We developed a new methodology to quantify PFAS contamination in water using Hope College's particle accelerator. To do this, we created an ~2000 PPM NaF in water standard and carefully controlled the experimental configuration. We are hoping that careful control of the experimental conditions will yield a consistent ^{19}F γ-ray count per Coulombs from Proton Induced Gamma-ray Emission (PIGE). 3.4MeV protons have enough energy to exit the particle accelerator, travel 27 mm in air, and penetrate into the liquid standard. As protons lose energy in the liquid, nuclear reactions such as (p, p'γ) with the ^{19}F and ^{23}Na nuclei create γ rays. The amount of beam incident on the sample was measured with Rutherford backscattering (fit with SimNRA – simulation nuclear reaction analysis software).

Results

The black line correlates the average concentration of fluoride in our NaF solution. The red dashed line correlates the average higher concentration due to evaporation in the sample cups. Liquid standards need to be recreated every two weeks. 5% error was given for RBS fitting. 2.2-9.6% was the range of uncertainty for IDL integration.

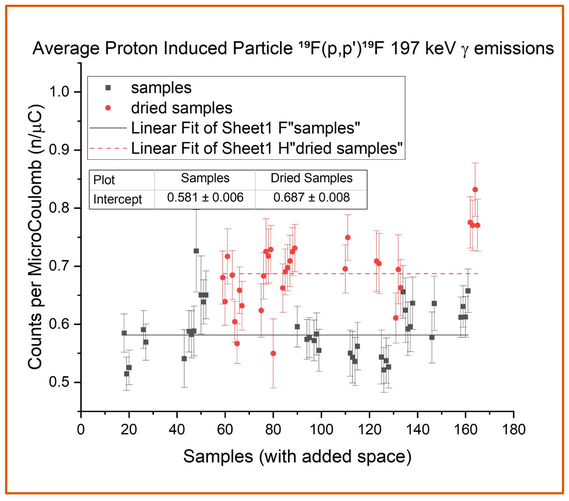

Figure 2. Dried grouping showed higher concentration on average and separation included to identify different measurement dates.

Methods

3.4 MeV protons (traveling at ~8.5% the speed of light) produced by the particle accelerator interact with a NaF standard causing $^{19}F(p, p'\gamma)^{19}F$ reaction. The γ emissions have energies of 110 keV and 197 keV. (See PIGE Spectrum) The γ rays are counted by a high purity germanium detector surrounded by a Compton scattering shield. Background is further reduced via vetoing counts from photomultiplier tubes. γ ray are integrated via an IDL fitting program and converted to counts per microcoulomb of proton interactions. (See section RBS fitting.)

Diagram of Chamber

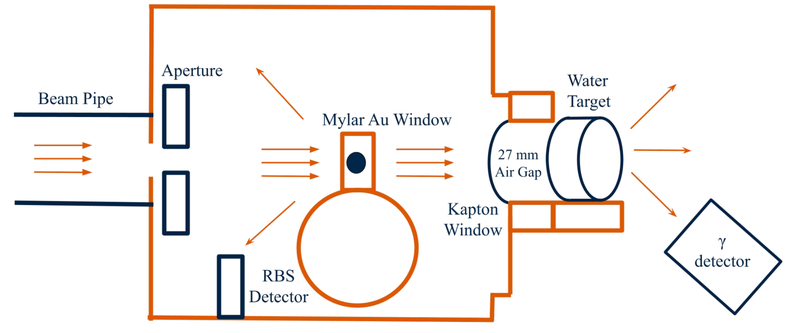

Figure 4. Schematic of the chamber.

Rutherford Backscattering (RBS)

γ ray counts are converted to counts per microcoulomb of proton interactions. MicroCoulombs (μ) are normalized with Rutherford backscattering spectroscopy. A silicon surface barrier detector is placed behind a thin mylar and gold window inside the chamber. Protons scatter backwards, in small amounts, and are collected by this detector. Simulate nuclear reactions analysis (SIMNRA) software models the expected counts or particles*steradian of backscattered protons which is directly proportional to the number of microcoulombs.

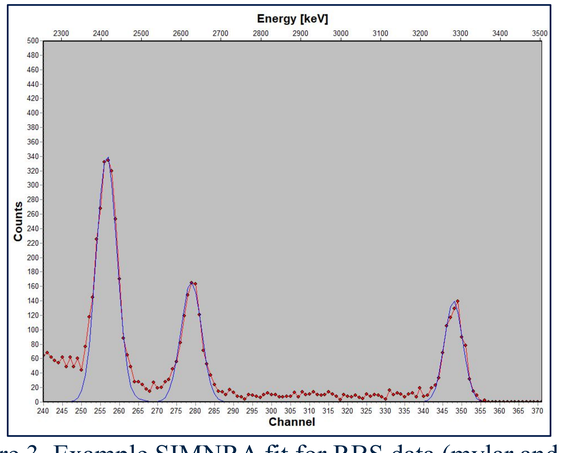

Figure 3. Example SIMNRA fit for RBS data (mylar and pure gold)

Fit Parameters	
Incident Ion	H^+
Energy	3.4 MeV
Exit Angle	13.6°
Calibration Offset	-20 keV
Energy per Channel	9.485 keV/CH
Particles* Steradian	2.10E+10
Detector Resolution	55

Conclusion and Future Work

- Liquid NaF standards need to be recreated every two weeks. This work will continue with liquid PFAS standards this summer.
- Count Rate Sensitivity to Air Gap, our collaborative poster, discussed experimental error in our research. (See related poster)

References

[1] Cruz, J., *The European Physical Journal Plus* 136, 969 (2021).
[2] "Investigations and Sites." Michigan.gov, (2020)