Particle Induced X-ray Emission Analysis of Atmospheric Aerosols in Upstate New York

Colin Gleason, Charles Harrington, Katie Schuff, Scott LaBrake and Michael F. Vineyard
Department of Physics and Astronomy
Union College, Schenectady, NY

Introduction

Elemental analysis of atmospheric aerosols collected in Schenectady, NY, was performed using particle induced X-ray emission (PIXE). This is part of a systematic study to identify the sources and understand the transport, transformation, and effects of airborne pollutants and the connection between aerosols, the deposition of pollution, and the uptake of pollutants by wildlife and vegetation. The aerosol samples were collected using a nine-stage cascade impactor which allows for the analysis of particulate matter as a function of particle size. The samples were bombarded with 2-MeV proton beams from the Union College Pelletron Accelerator and the energy spectra of emitted X-rays were measured with a silicon drift detector. The energy spectra were analyzed using the software program GUPIX [1] to extract elemental concentrations of the particulate matter.

PIXE

PIXE is an analytical technique used for elemental analysis [2]. A schematic of a basic PIXE experimental setup is shown in Figure 1. The sample of interest is bombarded with a beam of protons. Occasionally, a proton will knock an inner-shell electron out of an atom in the sample creating a vacancy. This allows an outer-shell electron to fill the hole, releasing an X-ray that can be detected. Each element emits characteristic X-rays which allow us to determine the elements present in the sample. The concentrations of the elements in the sample can be determined from the intensity of the emitted X-rays. The number of protons incident on the target is determined by integrating the charge on the Faraday cup for the case of thin targets.

The concentration C_Z of an element Z present in the sample is given by

$$C_z = \frac{Y_z}{Y_t \cdot H \cdot Q \cdot \varepsilon \cdot T}$$

where Y_Z is the intensity of the principle X-ray line for element Z, Y_t is the theoretical intensity per micro-Coulomb of charge, H is an experimental constant determined by taking data on a set of standards, Q is the measured beam charge incident on the sample, ε is the intrinsic efficiency of the detector, and T is the coefficient for transmission through any filters or absorbers between the target and the detector.

The use of PIXE for this type of analysis has a number of advantages over other analytical techniques. A broad range of elements can be analyzed simultaneously. The analysis is nondestructive so that other analytical techniques can be applied to the same samples. The technique provides good sensitivity with minimum detection limits on the order of 0.1 ng/m³ for impactor aerosol samples [2]. Also, the impactor foils can be used in the PIXE analysis without any sample preparation.

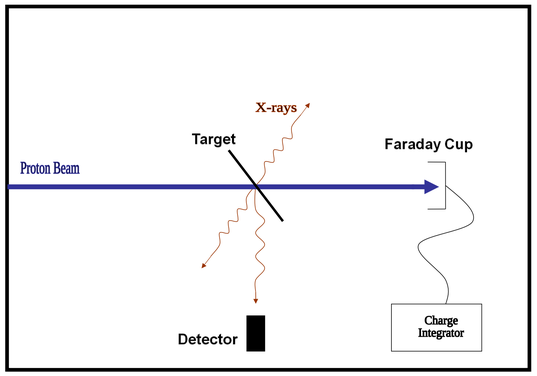

Figure 1: A schematic of a basic PIXE experimental setup for thin targets.

Sample Collection

The aerosol samples were collected in the historic Stockade District of Schenectady, NY. A nine-stage cascade impactor was used to collect the aerosols based on their particle size [3]. Shown in Figure 2 is a schematic and photograph of the impactor. The impactor was attached to a vacuum pump which drew air through the impactor at a rate of 1 L/min for approximately 44 hours. This corresponds to a total of approximately 2.7 m³ of air that flowed through the impactor. Particles of different aerodynamic diameter ranges were impacted on Kapton foils in each stage. The thin Kapton foils were removed and used as targets in the PIXE experiments with the accelerator.

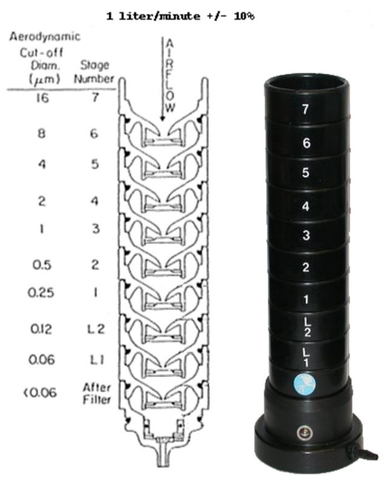

Figure 2: A diagram (left) and a photograph (right) of the nine-stage cascade impactor [3].

Experiment

The PIXE experiments were performed using the Union College Pelletron Accelerator shown in Figure 3. Proton beams with an energy of 2 MeV and a diameter of 2 mm were incident on the samples positioned at 45° to the beam in a small scattering chamber. Beam currents of 2 to 4 nA were measured in a Faraday cup behind the scattering chamber. The X-rays were detected with a silicon drift detector (SDD) at 45° to the target, after passing through a 76-μm thick Be vacuum window on the chamber. The SDD detector was calibrated using an ^{241}Am source. Energy spectra of the emitted X-rays were collected for all the aerosol samples and a set of Micromatter standards [4]. A picture of the scattering chamber, the Faraday cup, and the SDD detector is shown in Figure 4.

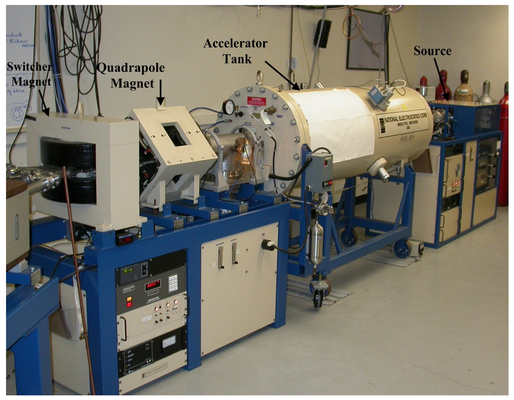

Figure 3: A photograph of the Union College Pelletron Accelerator showing the ion source, the accelerator tank, the quadrupole focusing magnet, and the switcher magnet.

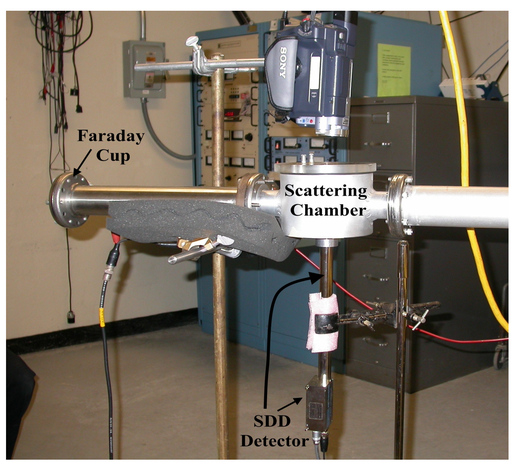

Figure 4: A photograph showing the scattering chamber, SDD detector, and Faraday cup.

Preliminary Results

The X-ray energy spectra were analyzed with GUPIX [1] software to extract the elemental concentrations in the aerosol samples. The first step in the analysis was to determine the H factor by fitting the spectra taken on the standards. Then the spectra taken on the aerosol samples were fit to determine the concentrations.

Shown in Figure 5 is a fitted PIXE spectrum for an aerosol sample of particulate matter with diameters between 4 and 8 μm. The extracted elemental concentrations for this sample are shown as a bar graph in Figure 6.

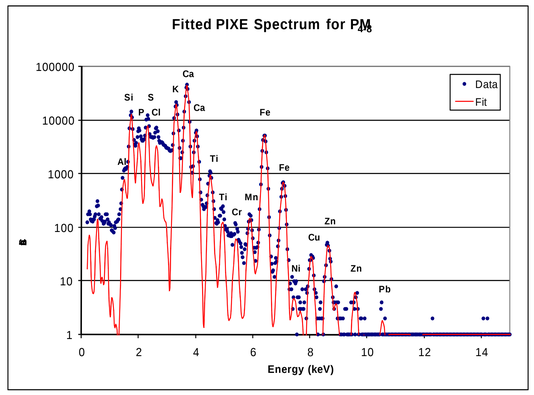

Figure 5: A PIXE spectrum for an aerosol sample of particulate matter with diameters between 4 and 8 μm. The red curve is a GUPIX [1]fit to the data.

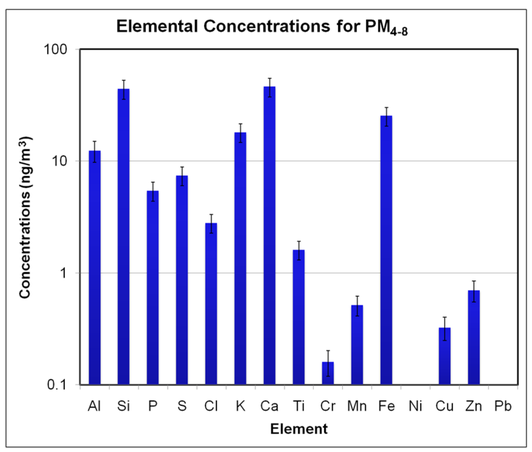

Figure 6: A bar graph of concentration versus element for an aerosol sample with particles between 4 and 8 μm in diameter.

References

[1] GUPIX, the versatile PIXE spectrum fitting software, University of Guelph.

[2] Johansson, Sven, John Campbell, and Klas Malmqvist. *Particle Induced X-Ray Emission Spectrometry (PIXE)*. New York, NY: John Wiley & Sons, 1995.

[3] PIXE International Corporation, P.O. Box 2744, Tallahasee, FL 32316 U.S.A.

[4] MicroMatter Co., 18218 18th Ave. NW, Arlington, WA 98223, U.S.A.

We would like to thank the NASA NY Space Grant, the Union College Davenport Fellowship Program, and the Union College Department of Physics and Astronomy for summer research support.