

Elemental Concentrations as a Function of Particle Size for Aerosol Samples Collected in Upstate New York from PIXE

Introduction

Using proton induced X-ray emission (PIXE) spectrometry, aerosol samples were studied to measure concentrations of airborne pollutants around Schenectady, New York. The health and climate effects of atmospheric aerosols depend on the size distribution of the particulate matter, which also is important for identifying the sources and for understanding the transport, transformation, and removal processes. For this reason, the aerosol samples were collected using a cascade impactor that separates the particulate matter into ten diameter ranges that allows for the analysis as a function of particle size. Beams of 2-MeV protons, provided by the Union College Pelletron Accelerator, were incident on the thin Kapton impaction foils, producing X-rays. The energy and intensity of the X-rays were measured using a silicon drift detector. The X-ray spectra were fit using the GUPIX software package [1] to determine the elemental concentrations of the aerosols as a function of particle size. The sample collection, PIXE experiments, and analysis are discussed, and preliminary results are presented.

Sample Collection

We collected aerosol samples in Schenectady's historic Stockade District along the Mohawk River. Our sample collection setup, as shown in Figure 1, included a vacuum pump, valve, nine-stage impactor, and flow meter. The pump pulls air through the impactor, which separates particulate matter according to size and captures it on Kapton foils at each stage [2]. The air flow rate through the system is controlled with the valve and measured using the flow meter. Our impactor was designed to handle a flow rate of 1 L/min. The system was operated for approximately 44 hours and sampled a total volume of air of about 2.7 m³. Shown in Figure 2 are optical microscope images of a blank Kapton foil (left) and a foil from the impactor that has captured aerosol particles with diameters between 2 and 4 μm.

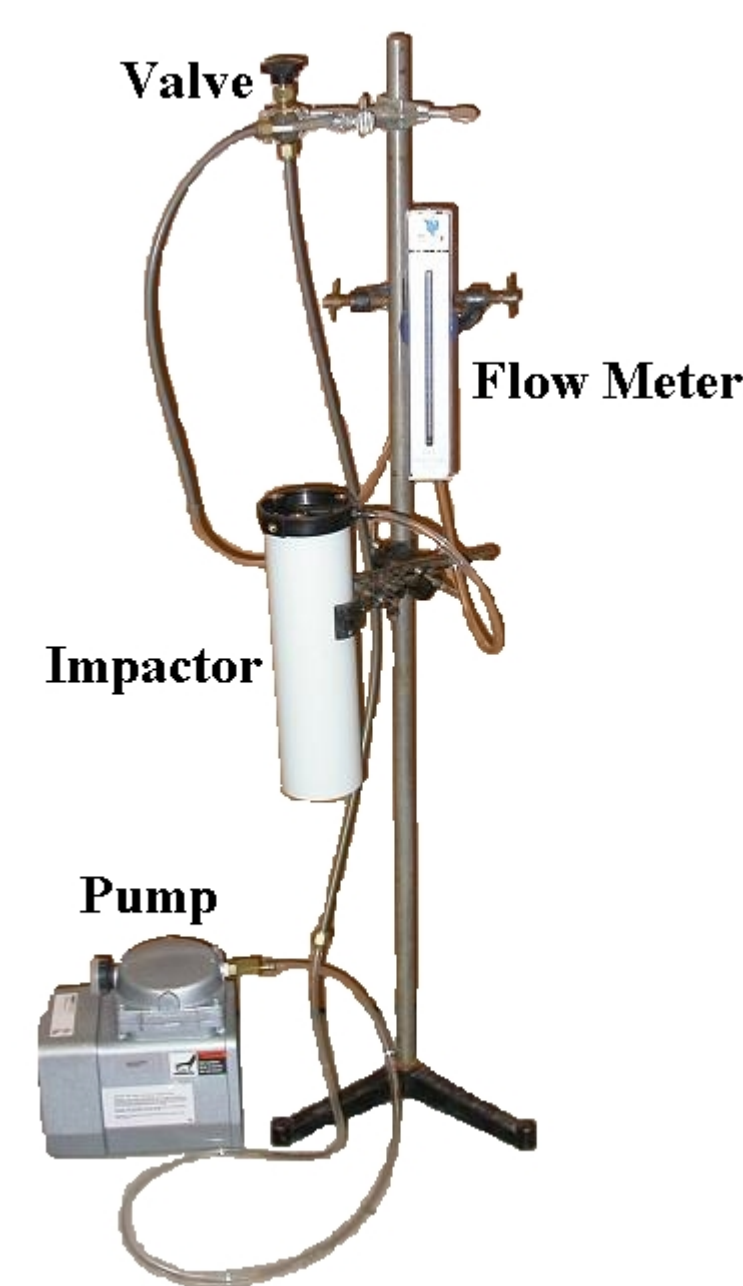


Figure 1: A photograph of our sample collection setup which includes the pump, valve, impactor, and flow meter.

Charles Harrington, Colin Gleason, Katie Schuff, Scott LaBrake, and Michael Vineyard
Department of Physics and Astronomy
Union College, Schenectady, New York

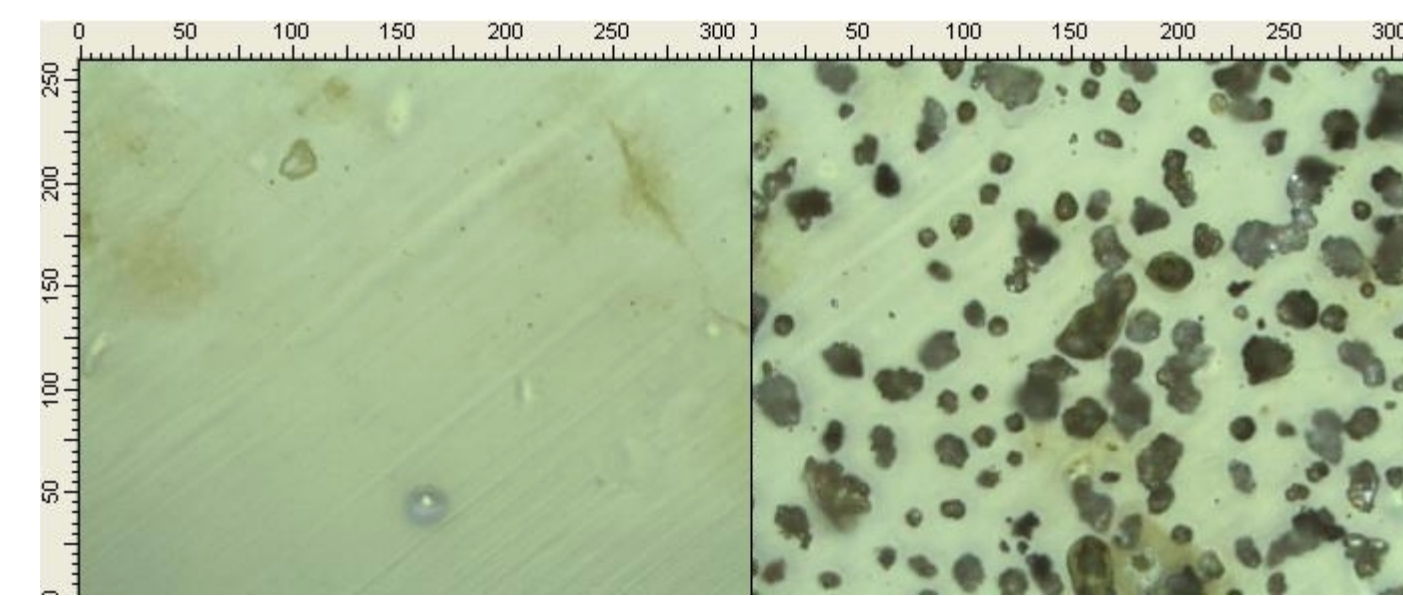


Figure 2: Optical microscope images of a blank Kapton foil (left) and a foil from the impactor that has captured aerosol particles with diameters between 2 and 4 μm.

PIXE Experiments

In PIXE, particle beams from accelerators are used to bombard samples. Some fraction of the time, a particle from the beam will eject an inner-shell electron from an atom in the sample leaving a hole. This hole can be filled by an outer-shell electron emitting an X-ray in the process. The elements in the sample are identified by the energy of the emitted X-rays while the concentrations of the elements are determined from the intensities of the X-rays. The PIXE technique allows for the simultaneous analysis of a broad range of elements with minimum detection limits on the order of a few tenths of ng/m³ for aerosol samples [3].

We used 2-MeV proton beams from the Union College Pelletron Accelerator to probe the aerosol samples and a silicon drift detector to measure the energies and intensities of the X-rays. The detector was calibrated with an Americium-241 source. Spectra were taken on the aerosol samples and on a set of Micromatter standards [4] to establish a normalization for the data. We collected 15 μC of charge on each of the aerosol samples and 1 μC on each of the standard foils. A PIXE spectrum taken on an aerosol sample with particulate matter between 2 and 4 μm in size is shown in Figure 3. Also shown in the figure is a spectrum taken on a blank Kapton foil for comparison.

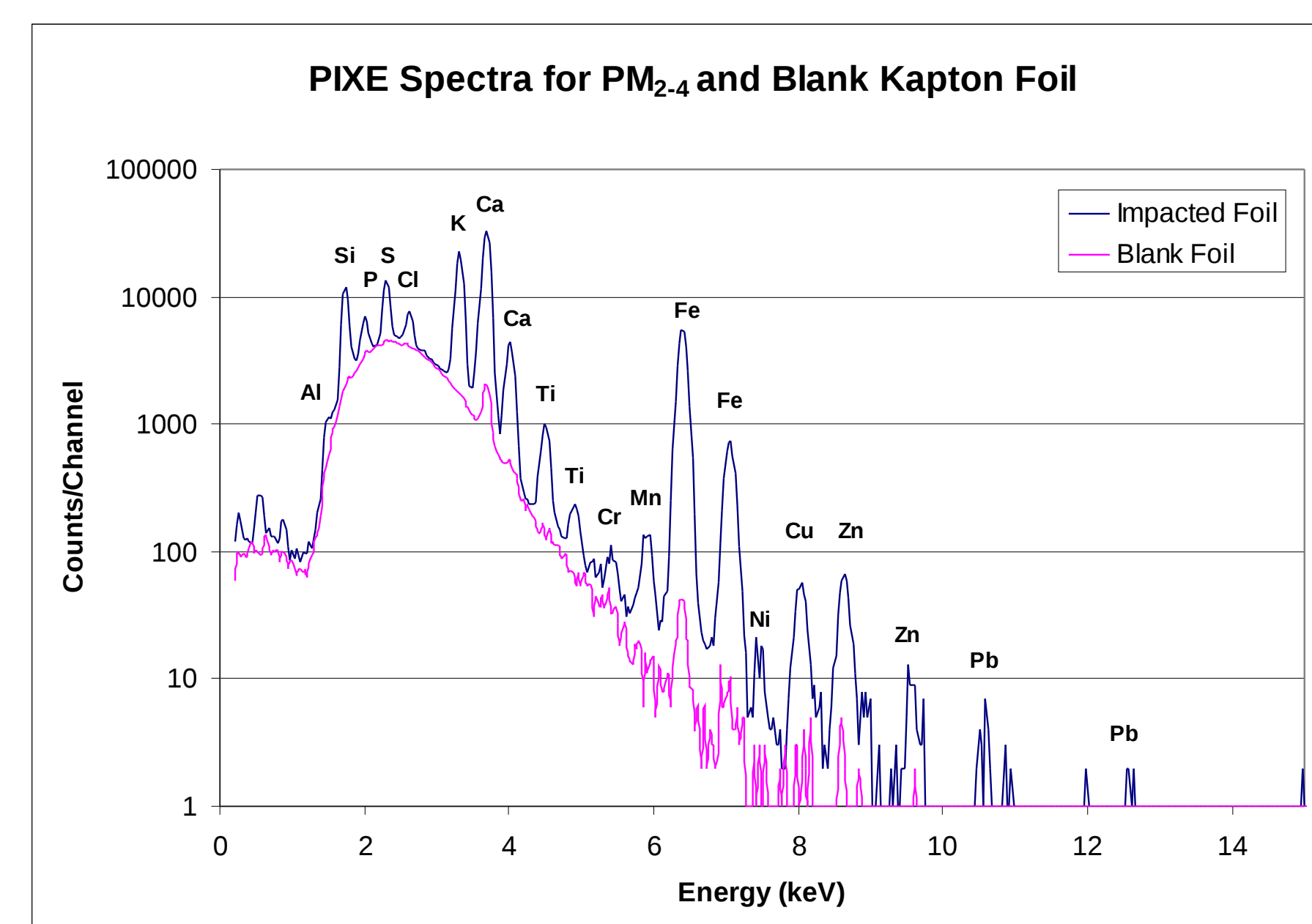


Figure 3: A comparison between PIXE spectra taken on an aerosol sample (blue) and a blank Kapton foil (pink). The sample was for particulate matter between 2 and 4 μm, and the peaks are labeled according to the corresponding elements. A total charge of 15 μC was collected for each spectrum.

Analysis

Using GUPIX software [1], we fit the PIXE spectra taken on the set of Micromatter standards [4] to determine an experimental factor to normalize our data. Then, using this factor, we fit our aerosol spectra to extract the elemental concentrations. Two of the fitted PIXE spectra taken on aerosol samples are shown in Figures 4 and 5.

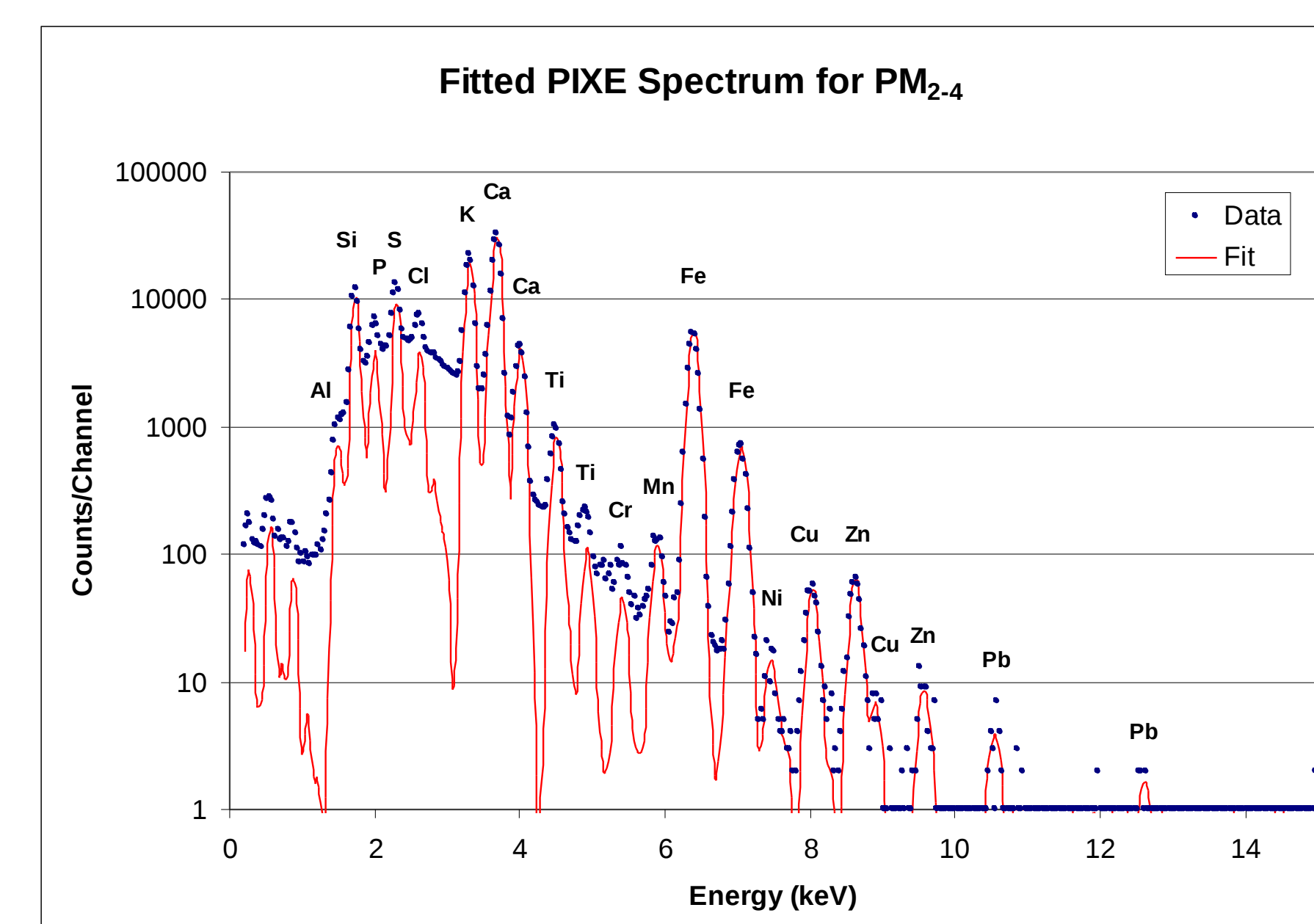


Figure 4: A PIXE spectrum taken on an aerosol sample with particulate matter in the 2 to 4 μm size range. The data are shown as blue points and the red curve is a fit to the data using GUPIX [1]. The peaks are labeled according to the corresponding elements.

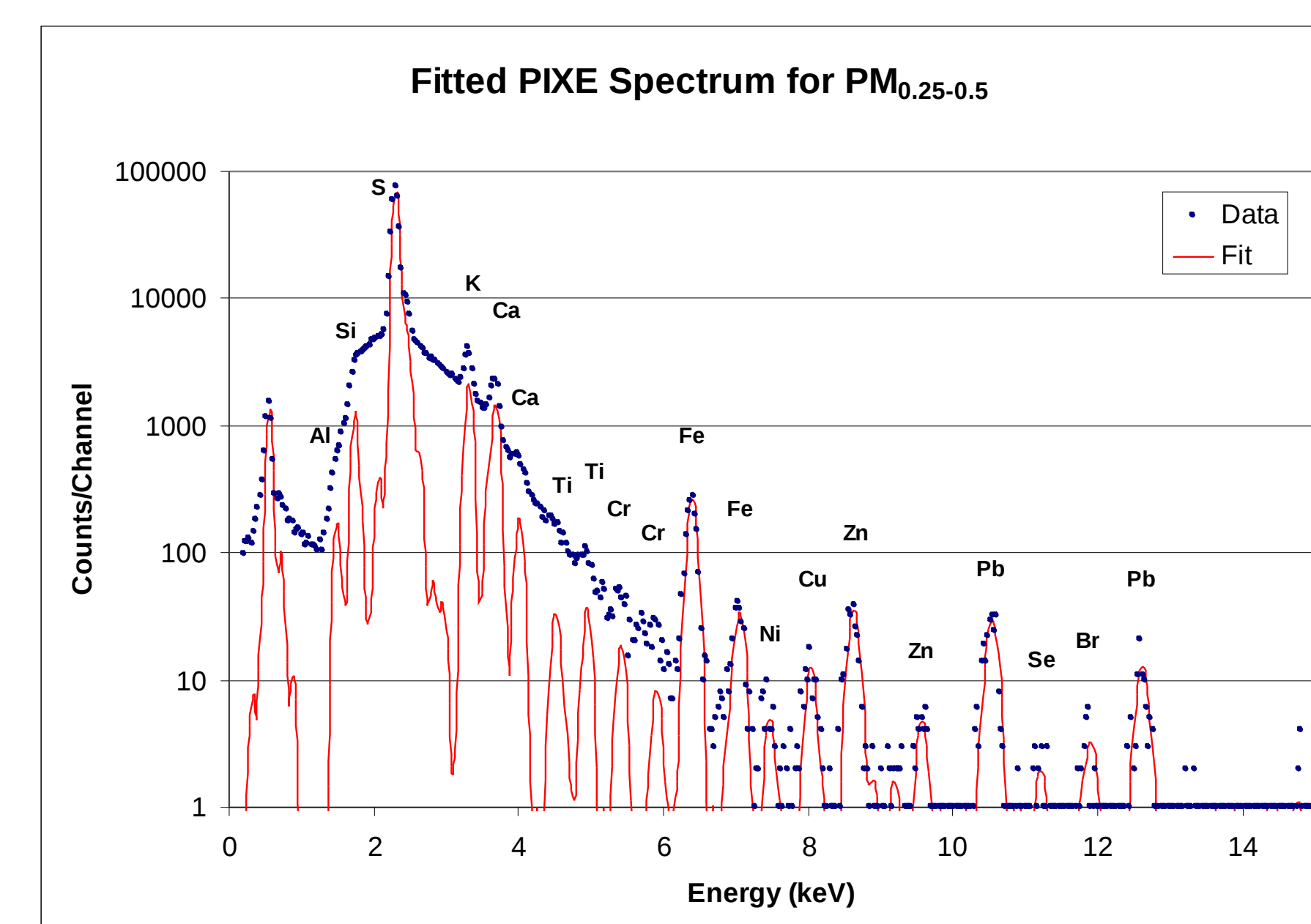


Figure 5: A PIXE spectrum taken on an aerosol sample with particulate matter in the 0.25 to 0.5 μm size range. The data are shown as blue points and the red curve is a fit to the data using GUPIX [1]. The peaks are labeled according to the corresponding elements.

Preliminary Results

Shown in Figure 6 are bar graphs of the elemental concentrations from aerosol samples for six different particle size ranges. Some interesting trends can be seen in the data. Note that there are considerable concentrations of sulfur in the aerosol samples, particularly for small particles. Sulfur is a main

component of acid rain and understanding the dependence of the concentration on aerosol particle size is important for addressing the acid rain problem in upstate New York. Also, there are measurable concentrations of lead in the small-particle aerosols. This observation certainly warrants further study because the toxicity of lead is well known and airborne contaminants with diameters less than 2.5 μm present special health risks since small particles get trapped in the lungs rather than the nose and throat [3].

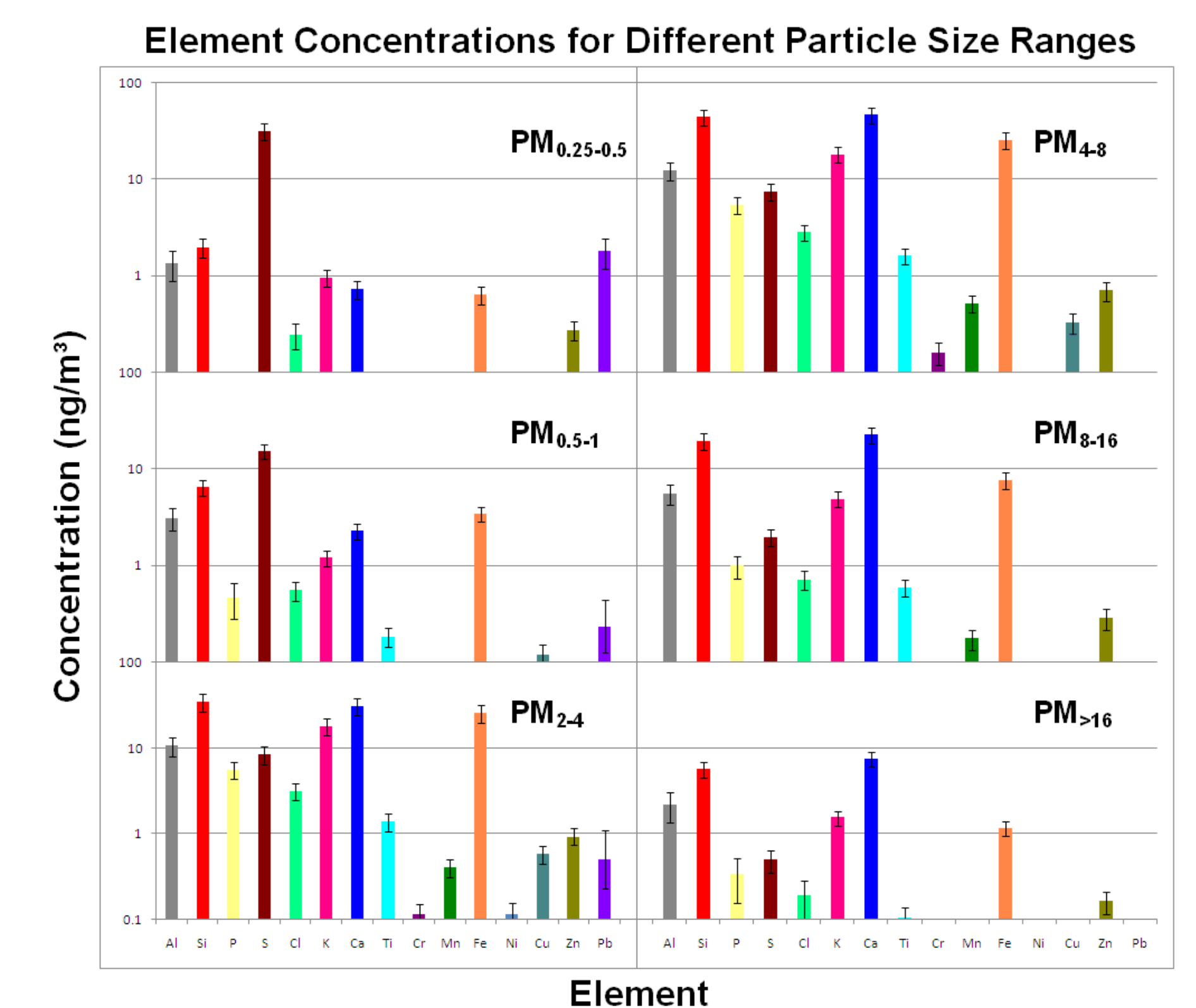


Figure 6: The elemental concentrations from aerosol samples for six different particle size ranges.

References

- [1] GUPIX, the versatile PIXE spectrum fitting software, University of Guelph, <http://pixe.physics.uoguelph.ca/gupix/main/>.
- [2] PIXE International Corporation, P.O. Box 2744, Tallahassee, FL 32316 USA, <http://pixeintl.com/>.
- [3] S.A.E. Johansson, J.L. Campbell, and K.G. Malmqvist, "Particle-Induced X-Ray Emission Spectrometry (PIXE)" (Wiley, New York, 1995).
- [4] MicroMatter Co., 18218 18th Ave. NW, Arlington, WA 98223, USA.

Acknowledgements

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

