Proton Elastic Scattering Analysis

Introduction

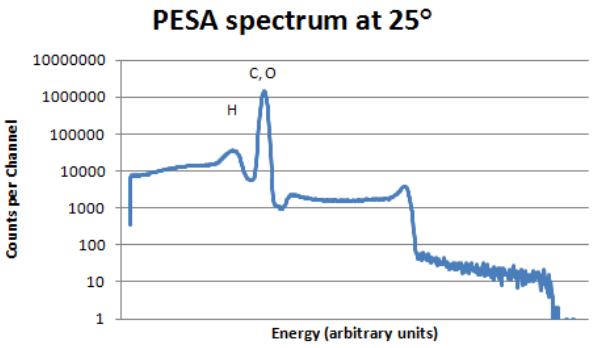
Environmental materials often have an unknown chemical makeup. With the Tandem Electrostatic Pelletron Particle Accelerator at Union College, the concentrations of various elements can be determined. The process of Particle Induced X-ray Emission (PIXE) and Particle Induced Gamma-ray Emission (PIGE) can determine the presence and concentrations of most elements, but the lightest element, hydrogen, is effectively invisible to these methods.

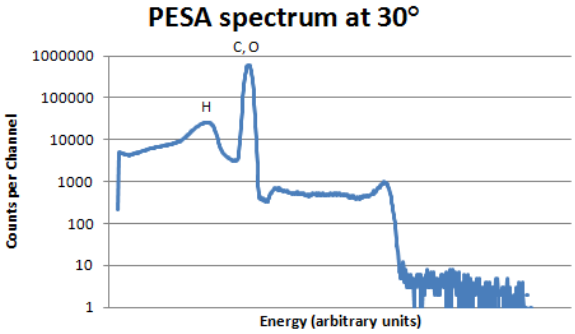
For determining the presence and concentrations of hydrogen, another method, proton elastic scattering analysis (PESA) can be used. This poster will deal with the process of analyzing a PESA spectrum.

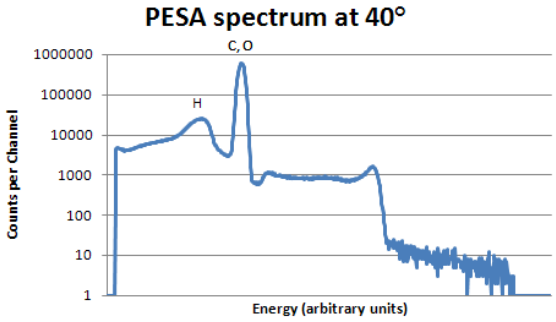
PESA

Proton Elastic Scattering Analysis (PESA) is a form of elastic recoil detection. When protons or alpha particles strike a hydrogen atom, the hydrogen bounces away from the beam. The hydrogen atom will strike the detector with a certain energy, dependant on the beam energy and the angle at which it off the beam.

With the Union College's tandem pelletron particle accelerator, we generated a proton beam of 1.8 MeV. The beam was directed onto a Mylar target. Relative to the beam line, we placed the silicon surface barrier detector at angles of 25, 30, and 40 degrees. When the beam interacted with the particles, protons could be knocked out of the sample, or protons could deflect off heavier particles. The graphs of the energies of the deflected particles had two main peaks: a peak for hydrogen, and a peak for all other elements.







Determining Yields

The important factors for determining how much hydrogen is present in a sample. Out of the total number of ions in the beam, a certain number will interact with a hydrogen atom and reflect It at the angle of the detector. The probability of this interaction is the scattering cross section, σ. But the cross section is usually given in the differential form of cross-section per solid angle, Ω. The solid angle is the ratio of the area of the detector to the distance between the detector and target squared. In simple terms,

$$\frac{N_{\text{det}}}{N_{inc} \times \frac{d\sigma}{d\Omega} \times \Omega_{\text{det}}} = nt$$

where nt is the number of hydrogen atoms per square centimeter in the target. Fully worked out,

$$nt = \frac{N_{\text{det}} \times r^2 \times 4KE^2 \times \sin^4\left(\frac{\theta}{2}\right)}{z^2 Z^2 N_{inc} A_{\text{det}}} \times \left(\frac{4\pi\varepsilon_0}{e^2}\right)^2$$

where N_{det} is the number of particles the detector picks up at a certain energy, r the distance between the target and the detector, KE, the kinetic energy of the beam, θ the angle between the detector and the beam line, z, the atomic number of the beam ions, Z, the atomic number of the target elements, N_{inc} the number of ions in the proton beam, A_{det} the area of the solid-state silicon barrier detector, ε_0 the vacuum permittivity constant, and e, the charge on a proton. The areal density is then converted from atoms per square centimeter to μg per square centimeter.

Conclusions and Further Work

As the graphs show, the greater the angle, the more counts are detected in each channel. An important thing to note is that there seem to be other peaks besides those of hydrogen and the large peak of other elements. We are not sure what causes those peaks. Most spectra we have found in papers cut off their spectra after the carbon/oxygen peak. A future task would be to determine exactly what causes the extra peaks.

Calibration is another challenge we had to deal with. To calibrate a detector to find alpha particles, we simply use an americium 241, as it emits alpha particles at a known energy. But we have no such calibration for protons. Ultimately, we came up with a calibration, but another future task is to find an effective calibration for our detector.

Though we have a formula to calculate yields, there are still problems. First, we regularly find the amount of hydrogen in the sample is greater than expected by about a factor of 100. We are still trying to unravel this mystery as well. Due to technical limitations, we were unable to run alpha particles on the accelerator this summer, so we have no alternative data to calculate yields from. Once we are able to fix the high energy column on the accelerator, we should be able to use alpha particles to test our current PESA spectra.

In conclusion, we have determined that we are capable of taking PESA spectra. However, calculating yields is a task still in development. Future research will include taking spectra with alpha particles and experimenting with other methods of calculating yields.

References

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