RUTHERFORD SCATTERING

REFERENCES

Experiments in Modern Physics, Mellissinos, pgs. 231-252
M.I.T. Rutherford Scattering Lab Manual
"The Laws of Deflexion of Alpha Particles Through Large Angles",
Geiger and Marsden

THE APPARATUS

We use a set-up very similar to that described in Mellissinos. Photocopies of the relevant pages from the references list above can be found in your lab manual. Follow the procedures outlined therein. Our apparatus consists of a basic vacuum system, a Bell jar, a fixed solid state detector, a rotatable source holder/collimator and gold foil scatterer assembly, and associated amplifiers and Pulse Height Analyzer. A schematic drawing of the UCI apparatus follows this text.

The alpha source is 500 micro-curies of Curium 244. You should be familiar with the decay scheme and product energies. Also familiarize yourself with radiation safety practices. The Curium source is plated with an extremely thin layer of metal to help contain the radioactive material. Over time (years), this metal film can deteriorate due to continual alpha bombardment. Do not directly handle the source or the surfaces it comes into direct contact with. Use the radiation monitor to check for fragments, and use disposable gloves to handle all components within the bell jar. Alpha particles do not penetrate the skin, but this type of source is hazardous if any of the material is ingested or inhaled.

The experiment must be done in a vacuum, at pressures below 500 mm Hg (Torr). Be familiar with the principals and techniques used in the operation of vacuum apparatus. The
mechanical vacuum pump is switched on using the switch on the pump. There are two valves which control the flow of air. Both valves should never be open at the same time. You will find that in order to remove the bell jar from the platform, it will be necessary to bring the chamber up to atmospheric pressure. One valve on the bell jar is used for venting. The other valve controls the flow of air from the bell jar to the pump. This valve should be open all the way while pumping, and closed when venting.

The scattering angle can be varied using the rotary feedthrough below the bell jar. The scatterer can be rotated through 180 degrees using the 20:1 gear reduction unit mounted to the rotary shaft. A potentiometer is geared to the feedthrough shaft, and a digital voltmeter displays a voltage that is proportional to the position angle of the shaft. 180 degrees of rotation produces a change of 9 volts, so the conversion factor is .05 volts per degree. Find 0 degrees by locating the point of maximum count rate.

In calculating the solid angle of the alpha source you will have to know some of the dimensions of the apparatus, such as: the width of the collimator slit, the distance between the source and the gold foil, the distance between the foil and the detector slit, and the area of the detector slit, taking into account the sensitive area of the detector. Make these measurements carefully. Be sure not to touch the Gold foil or the surface of the detector, as these are quite easily damaged. The thickness of the gold foil is .0025 mm.

You must also measure the width of the collimated alpha beam without the foil scatterer. Since handling the delicate foils is not advisable, we recommend replacing the entire gold foil holder with an identical holder (without foil). The aluminum collimator/slit assembly is removable, and can be placed into the appropriate holder. The holders are threaded onto the rotary feedthrough shaft. Hold the locking nut with a wrench, and turn the holder counter-clockwise for removal.

ELECTRONICS

SURFACE BARRIER DETECTOR

In the advanced lab we now have the opportunity to use more modern equipment than that used in the reference papers. So while the equipment may be different, the techniques are substantially the same. Refer to the drawing, fig. 1.

Be familiar with the principals of operation of the surface barrier detector. Refer to the technical publication "Solid State Detector Theory" in your lab manual. We use a detector with the following specifications:

- Active Area ............. 25 square mm
- Alpha Resolution ........ 15 Kev F.W.H.M.
- Depletion Depth ........ 100 microns
- Entrance Window ......... <40 micrograms/square cm Gold
- Bias Voltage ............ +50 VDC

The detector is light sensitive, so it must be kept in the dark at all times when bias voltage is applied. Also, do not apply bias voltage when the pressure is above 500 Torr. Always turn the bias voltage down before turning the NIM bin supply on or off.

The calibration of the bias voltage knob is reasonably accurate, so you may rely on it
to adjust the voltage. Note that the scale reads zero to 10 not zero to 100! The high internal resistance of the supply makes direct measurement difficult. The bias supply has been modified to produce a maximum of 100 volts. A setting of 5.0 will give 50 volts, which is the recommended voltage.

The surface barrier detector is a solid state device that produces charge in proportion to the energy of an ionizing particle.

**PRE-AMP**

The output of the surface barrier detector is coupled to a charge sensitive pre-amp. The pre-amp functions as a charge to voltage converter, and it buffers the detector from the capacitive loading effects of the co-axial cables, and the input of the shaping (spectroscopy) amplifier. Consequently, the shortest possible cable should be used between the detector and pre-amp to minimize capacitance and micro-phonics.

The pre-amp requires an auxiliary power supply connection, such as that found on the back of the Canberra DDL NIM module.

**SPECTROSCOPY AMPLIFIER**

The output of the pre-amp is coupled to a shaping amplifier (also called a spectroscopy amp). Its function is to increase the signal pulse amplitude to a range appropriate for matching it to the input sensitivity of the multi-channel analyzer. The gain adjustments on the amplifier essentially control the energy sensitivity of the analyzer. Optimum adjustment of the time constant/filter switches can improve the signal to noise ratio by integrating out some of the high frequency noise.

The polarity of the signal may be inverted, as necessity dictates, by using either the 'Pos' or 'Neg' inputs. For our system, use the 'Pos' input. Adjust the gain so as to produce pulses with an amplitude in the range of 0 to 8 volts in order to match the input sensitivity range of the PCA-II pulse height analyzer.

**DISCRIMINATOR**

The purpose of the discriminator is to establish a signal pulse amplitude threshold, below which all pulses are systematically eliminated. Low amplitude pulses are generally more frequent than pulses whose amplitude lies in the range of interest. Low amplitude pulses are also usually associated with electronic noise, multiple scattered alphas, and other background noise sources. Since these counts may have a tendency to obscure your data, it is desirable to adjust the threshold voltage on the discriminator high enough to mask out this noise and improve counting statistics.

The discriminator is basically a voltage comparator that compares the amplitude of an analog input signal with an adjustable threshold voltage. An LLD (low level discriminator) accepts analog pulses at it's input, and produces logic pulses at it's output when the amplitude of the input pulse exceeds the preset threshold.

An upper level discriminator systematically masks pulses whose amplitude is greater
than the threshold setting. For this experiment the ULD should be set at its maximum as a
default.

The PCA-II has built-in lower level and upper level discriminators which are adjustable
on the rear panel of the computer.

MCA/PHA

The multichannel analyzer or pulse height analyzer is a recording/storage instrument
that produces an X-Y plot of counts (Y-axis) versus pulse height (X-axis). Since the
amplitude or height of a pulse is proportional to the energy of the particle, the PHA histogram
represents an energy spectrum.

The PHA only registers a count when the input pulse amplitude falls between the
upper and lower discriminator thresholds.

In order to calibrate the X-axis in terms of energy, you will have to correlate channel
number with energy for at least two different alpha energies. In addition to the Cm 244, you'll
find a low activity Americium 241 source in the lab. Look up the energies for the alphas from
each of these sources, and then measure the channels in which the peaks appear. (Use a
mathematical method to find the centroid.) The difference in the energy of the particles,
divided by the difference in channel number gives you the calibration factor in MeV per
channel.

Your data can be stored on disc in an ASCII format for import into curve fitting/plotting
programs such as Sigma Plot. Data in these files appears as two columns of numbers;
col(1)-channel number, and col(2)-number of counts. Spectra can also be plotted out directly
from the controlling software.

A useful feature of the PCA-II is the region of interest (ROI) mode. The analyzer will
integrate for you, all of the counts within a certain pre-defined energy region. This is useful
because you can choose to count only the higher energy alphas, and not those which may
have undergone multiple scatterings. (This can be done with the discriminator also, but
pulses falling below the threshold are not recorded.)

For further information on any of the equipment, please consult the manuals.