PHYSICS 510 N-O

GAMMA-RAY SPECTROSCOPY

Gamma rays passing thru at Nal (Ti) crystal are detected by the electrons they produce in the crystal by one of three processes: photo-effect, Compton scattering, and pair production. Electrons, or any charged particles traversing the crystal, lose energy by ionization and excitation of the crystal atoms. NaI (Ti) will scintillate on the passage of a charged particle. The number of photons emitted by the crystal is proportional to the energy lost in the crystal by the charged particle. Some constant fraction of these photons are collected on the photo-sensitive cathode of a photomultiplier. The photo-electrons emitted by the cathode are amplified in the multiplier, the output appearing as a current pulse on the anode of the photomultiplier. The preamp converts it to a voltage pulse. The crucial point is that the voltage pulse is proportional to the energy lost in the crystal by the charged particle. Thus if a gamma ray converts all of its energy to electrons, either thru the photoelectric effect or by a cascade process such as Compton scattering followed by photo- electric absorption of the scattered "(-ray, the output voltage pulse will be proportional to the energy of the incident gamma ray. This is discussed in detail in the references.

Apparatus

The equipment is:

i) a RIDL scintillator, photomultiplier and preamplifier assembly (Model 10- 17).

ii) the amplifier portion of a RIDL amplifier and single channel analyzer module (Mode133-13A).

iii) a RIDL HV(high voltage) supply

iv) a Nuclear Data pulse height analyzer that is a card plugged into an IBM PC.

Schematically the apparatus can be represented as follows:

Procedure

1) Observe the amplifier output on an oscilloscope. Use a CS137 source and adjust the HV and amplifier gain so that the peak in the distribution is at about 3 V. This will make sure that the output isn't saturated (the tops of big pulses squared-off) for most of the other sources. Photograph the oscilloscope trace and explain it in your write-up.

2) Become familiar with the operation of the pulse height analyzer. A summary of instructions and a chapter from the user's guide are included in the book for the experiment.

3) Observe the Cs137 pulse height distribution. The 'Y-ray energy is 0.662 Me V, and the peak in the distribution corresponds to the full energy of the 'Y-ray being absorbed in the NaI crystal. Calibrate the pulse height analyzer. Measure the pulse height distribution, and explain its features in your report.

4) Measure the pulse height spectra of Co60, Na22, and MsTh. Identify the various features of these spectra and determine the energies of all the 'Y-rays. Compare your results with published results.

5) Look for a small peak at low energies (~80 ke V) using a Pb slab as a source backing. Repeat with a Ta backing. Explain the results.

Calculations and Questions

I) Using the information from the references calculate the ratio of the photoelectric, Compton, and pair production cross sections for the gamma-rays observed.

II) What is the mean free path of a 1 MeV gamma-ray in NaI?

III) Calculate the pulse height distribution expected for Cs137 taking secondary processes into account. An example of such a secondary process is Compton scattering followed by photoelectric absorption of the scattered gamma-ray. The NaI crystal is 3.8 cm in diameter and 3.8 cm thick.

IV) Describe some ways of measuring gamma-ray energies. Indicate the energy range over which the various techniques are useful.

References

Bleuler: Experimental Nucleonics, P. 305-316.

Hofstader & Mclntyre: Nucleonics (3) 32, September (1950)

Segre: Experimental Nuclear Physics, Vol. 1, p. 304-344. Not necessary to read in detail. Useful for information about the passage of radiation thru matter.