(NU3-10) Gamma Absorption

Aim of experiment

The determination of the linear and mass absorption coefficient in Pb absorber

Apparatus

GM tube counting station consists of GM counter – radioactive source Cs^{137} and/or Co^{60} ,source holder-stop watch, Pb thin sheets, source cabinet made of thick lead.

Theory of experiment

A nucleus which is in an excited state may emit one or more photons (packets of electromagnetic radiation) of discrete energies. The emission of gamma rays does not alter the number of protons or neutrons in the nucleus but instead has the effect of moving the nucleus from a higher to a lower energy state (unstable to stable). Gamma ray emission frequently follows beta decay, alpha decay, and other nuclear decay processes.

When a beam of particles strike any material, particles are removed from the beam as they interact with the atoms and molecules of that material. The particles that are lost from the beam are said to be absorbed. This experiment will be concerned with the absorption of photons (gamma rays)

Three important processes act to remove photons from a beam: the photoelectric effect, the Compton Effect, and pair production. The photoelectric effect is most significant at low photon energies and involves a collision of the photon with a bound atomic electron. The photon gives up all of its energy to the electron that is excited to either a higher energy level or the continuum.

At intermediate photon energies of less than about 2 MeV, the Compton Effect is important. In the Compton Effect the photon is scattered from a loosely bound electron, giving up only a portion of its energy. If the photon energy is sufficiently high, the photon may be transformed into an electron-positron pair in the vicinity of a nucleus and hence is removed from the beam. This process is known as pair production.

Regardless of the absorption process involved, the intensity I of the photon beam is found to decrease exponentially as the thickness x of the absorbing material increases according to the equation:

$$I = I_0 e^{-\mu x} \quad (1)$$

where I is the beam intensity after passing through the absorber, I_0 is the initial beam intensity, μ is the linear absorption coefficient, and x is the thickness of the absorber.

Taking the natural logarithm of both sides of Eq. 1 produces a linear relationship between $\ln I$ and x, namely,

$$\ln I = -\mu x + \ln I_0 \qquad (2)$$

If $x_{1/2}$ is the absorber thickness at which $I = I_0/2$, then it can be shown that

$$\mu = \frac{\ln 2}{x_{1/2}} = \frac{0.693}{x_{1/2}} \qquad (3)$$

As one might expect, the absorption coefficient depends both upon the absorbing material and the energy of the incident photons. When comparing absorption coefficients of different materials, it is convenient to define the mass absorption coefficient μ_m as

$$\mu_m = \frac{\mu}{\rho}$$

where ρ is the mass density of the absorbing material (in g/cm^3). If μ is in cm^{-1}, the units for μ_m will be cm^2/g.

Procedure

1. Set the high voltage to the value specified on the tube holder.
2. Set the clock to preset the running time.
3. Set the time to 90 s. This preset time is not to be changed during the experiment.
4. Click Data collection. It will stop 90 s after it starts.
5. When counting ceases, record number of counts, which is N_{bg} in this case .
6. In order to obtain better statistics, set time at longer collection time.
7. Use the tweezers to place the Cs^{137}- source in the plastic tray and slide the tray into the third slot from the top.
8. When counting ceases, record number of counts, which is N_0 in the case of no absorber.
9. Clear the data. Measure and record the thickness of the first pieces of lead that is provided and insert the piece into slot 2 just midway the sample and detector. Collect data. Record the number of counts, which is the number of counts at first Pb sheet thickness.
10. Repeat the process described in step 8 until all the sheets of lead that have been provided are placed between the sample and Geiger tube.

(NU3-10) Gamma Absorption

Results

N_{BG} = counts/ s

Pb Thickness, x (cm)	N(t) counts/s	$N=N(t)-N_{bg}$ counts/s	Ln (N)

11. Plot the number of counts per second (on a ln scale as the ordinate) vs. absorber thickness (on a linear scale as the abscissa). From the slope, determine μ and μ_m.
15. From the calculation of μ_m for lead using the Cs^{137}- source, read the graph (available in the lab) to determine the gamma ray energy. Compare this energy with the accepted value of 0.66 MeV and calculate the percentage error.

Edusoft

Innovate to educate