
Report T2 - Gamma spectroscopy and Compton scattering

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1 Introduction

In this experiment we want to analyse the Energy of photons emitted by radioactive probes with a szintillaor detector. First we will use Materials with low radiation and with well known energy peaks to calibrate the detector. Then we will use that to analyse the spectrum of a source with stronger radiation and establish a link between scattering angle and the energy of compton scatterd photons.

2 Gamma spectroscopy

2.1 Theory

We are looking at photons with energies from 5keV up to 2Mev. They are three relevant interactions of photons with matter within this energy range.

Photoelectric effect ($E_\gamma \sim E_B$):

Incoming photon with energy E_γ is absorbed by an electron with binding energy E_B . That electron leaves the Atom with kinetic Energy $E_{\text{kin}} = E_\gamma - E_B$. X-ray radiation follows because of the empty position being filled by an electron of a higher shell.

Compton scattering ($E_\gamma \gg E_B$):

Incoming Photon is scattered at an electron. It is not absorbed but transmits energy to the electron. The maximum transmitted energy is given by E_C . That maximum is obtained through frontal collision (scattering angle $\theta = 180^\circ$).

Pair production ($E_\gamma \geq 2m_e c^2(1 + \frac{m_e}{M})$):

If the Energy is greater than the mass of two electrons, the photon can decay in a positron and an electron. Given an additional interaction partner with mass M for momentum conservation, a (non-virtual??) positron-electron-pair can be produced. This pair then decays into two photons.

The expected energy peaks for an incoming photon with energy E_γ are the following:

Photo peak at $E_\gamma \leftarrow$ All energy is absorbed.

Compton edge at $E_C \leftarrow$ Compton collision with frontal collision and undetected scattered photon.

Escape peak at $E_{\text{esc}}^{(1)} = E_\gamma - m_e c^2 \leftarrow$ Pair production with one undetected final state photon.

Double escape peak $E_{\text{esc}}^{(2)} = E_\gamma - 2m_e c^2 \leftarrow$ Pair production with two undetected final state photon.

Backscatter peak $E_R = E_\gamma - E_C \leftarrow$ Compton effect outside of the scintillator with absorption of the scattered photon.

2.2 Setup

A radioactive probe is placed in front of the scintillator at distance r_0 .

[3.67252799e+07 1.83263680e+04 4.60050810e+03 4.59613372e+03 8.63618713e+02]

	Cs-strong	Cs-weak	Co	Eu	Na
Buy date	23.11.2010	12.08.1988	15.04.2003	02.06.1978	12.01.2005
Activity at buy date [Bq]	$44\,400 \times 10^3$	37×10^3	37×10^3	37×10^3	37×10^3
Halflife time [s]	950×10^6	950×10^6	$16\,634.6 \times 10^4$	4270.8×10^5	8212.3×10^4
Halflife time errors [s]	7.8×10^6	7.8×10^6	3.5×10^4	4.4×10^5	3.5×10^4
Decay constant [s ⁻¹]	7.3×10^{-10}	7.3×10^{-10}	4.2×10^{-9}	1.6×10^{-9}	8.4×10^{-9}
Activity today [Bq]	36 725 279.9	18 326.4	4600.5	4596.1	863.6

Table 1

3 Compton scattering

3.1 Theory

Energy of scattered photons: $E'_\gamma = E_\gamma \cdot \frac{1}{1+a(1-\cos\theta)}$

count rate: $m = \frac{A \cdot I_\gamma}{4\pi r_0^2} \cdot \eta \cdot \epsilon \cdot N_e \cdot \frac{d\sigma}{d\Omega} \cdot \frac{F_D}{r^2}$

3.2 Setup

3.2.1 conventional geometry

The source is placed on the edge of a rottary table, allowing different angles. In the middle of the table we place the scattering body (either a steel or an aluminium cylinder). To shield the radiation coming directly from the source from the detector, we use convenientl shaped lead coils.

Distance from source to scattering body: $r_0 = 49(1)$ mm

Distance from scattering bod to detector: $r = 272(1)$ mm

3.2.2 ring geometry

The source is aligned with the detector, but shielded of it by a lead clinder in the middle. The scattering body is an aluminium ring and the whole experiment is axially symetric.

ring size	outer diameter d_o	inner diameter d_i	diameter d
small	149(1) mm	121(1) mm	149(1) mm
medium	199(1) mm	171(1) mm	149(1) mm
large	250(1) mm	221(1) mm	149(1) mm

Table 2