T2
Gamma spectroscopy and Compton scattering

Group 14

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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 ernegies 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 Eg is absorbed by an electron with binding ernergy E_B. That elctron leaves the Atom with kinetic Energy $E_{\text{kin}} = E_\gamma - E_B$. X-ray radiation follows because of the empty position beeing filled b 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 enrgy to the electron. The maximum transmited energy is given by E_C. That maximum ist obtained through frontal collision (stattering angle $\theta = 180°$).
Pair production ($E_\gamma \geqslant 2m_ec^2(1 + \frac{m_e}{M})$):
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 $E^{(1)}_{\text{esc}} = E_\gamma - m_ec^2 \leftarrow$ Pair production with one undetected final state photon.
Double escape peak $E^{(2)}_{\text{esc}} = E_\gamma - 2m_ec^2 \leftarrow$ Pair production with two undetected final state photon.
Backscatter peak $E_R = E_\gamma - E_C \leftarrow$ Compton effect outside of the scintillator with absorbtion 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 (kBq)	44400	37	37	37	37
Halflife time (days)	$(1.100 \pm 0.009) \times 10^4$	$(1.100 \pm 0.009) \times 10^4$	$(1.9253 \pm 0.0004) \times 10^3$	$(4.943 \pm 0.005) \times 10^3$	$(9.505 \pm 0.004) \times 10^2$
Decay constant (s^{-1})	$(7.29 \pm 0.06) \times 10^{-10}$	$(7.29 \pm 0.06) \times 10^{-10}$	$(4.1669 \pm 0.0009) \times 10^{-9}$	$(1.623 \pm 0.002) \times 10^{-9}$	$(8.440 \pm 0.004) \times 10^{-9}$
Activity today (kBq)	$(3.673 \pm 0.006) \times 10^4$	$(1.83 \pm 0.01) \times 10^1$	$(4.602 \pm 0.002) \times 10^0$	$(4.60 \pm 0.01) \times 10^0$	$(8.64 \pm 0.01) \times 10^{-1}$

Table 1: A compilation of all radioactive sources used in the experiment, with corresponding activities computed according to the decay law.

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: $r_0 = 49(1)\,\mathrm{mm}$
Distance from scattering bod to detector: $r = 272(1)\,\mathrm{mm}$

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