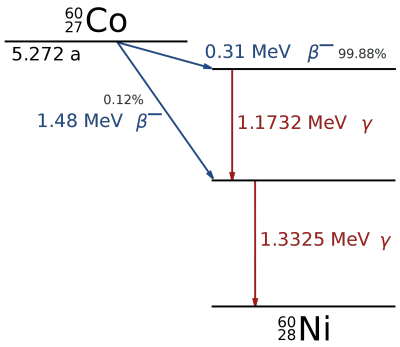
γ-Spectroscopy

Abstract

In this experiment various γ-ray emitting samples are investigated with two most commonly used detectors in γ-spectroscopy, a NaI(Tl) scintillation detector and HPGe detector, and their activity measured.

Physics

γ-radiation is emitted by excited nuclei as a result of nuclear decay (e.g. α- or β-decay) or a nuclear reaction. As an example the decay scheme of ^{60}Co shows that two γ-rays are following the β-decay:



Interaction of γ-rays with matter

3 major types of interaction mechanisms:

photoelectric absorption

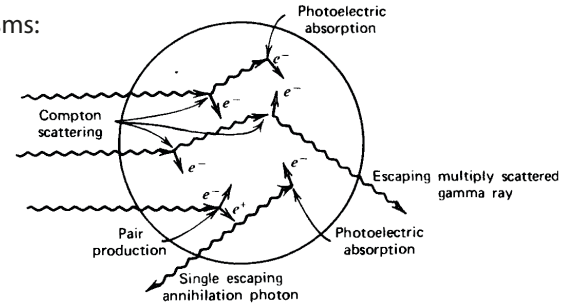
$E_{e^-} = h\nu - E_b$

Compton scattering

$E_{e^-} = h\nu - h\nu'$

pair production

$E_{e^-} + E_{e^+} = h\nu - 2\, m_0 c^2$



The number of interactions of radiation with matter depends on the sum of cross sections σ of all involved processes:

$$dN(x) = -N(x)\, \sigma\, n\, dx$$

As a result, the initial intensity of a γ-radiation, N_0, decreases exponentially with penetration depth, x, with $\mu = \sigma\, n$ the linear attenuation coefficient:

$$N(x) = N_0 e^{-\mu x}$$

The activity of the sample is calculated from the intensity of the photopeak, which corresponds to the full energy of the γ-ray:

$$A = N_{photo} / (\Omega/4\pi\, \varepsilon(E_\gamma)\, \Gamma(E_\gamma)\, \omega(E_\gamma)$$

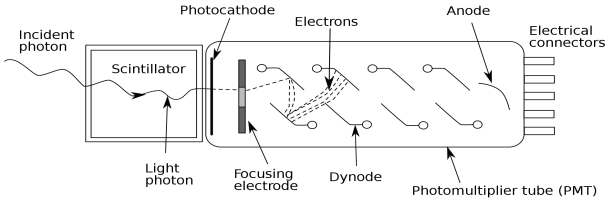
$\Omega/4\pi$ ... solid angle
$\varepsilon(E_\gamma)$ ... total efficiency
$\Gamma(E_\gamma)$ ... photopeak to total ratio
$\omega(E_\gamma)$ ... absolute intensity of γ-ray

Detectors

Two types of solid state detectors are commonly used for γ-spectroscopy:

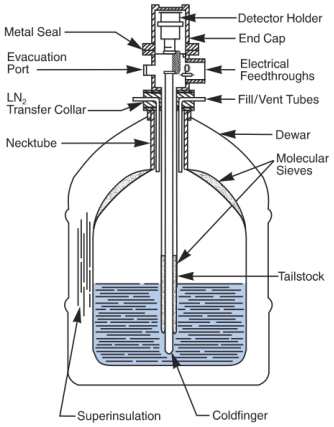
inorganic scintillation detectors - NaI(Tl) detector

the absorbed γ-ray energy is converted to photons, the photocathode converts photons to electrons, which are amplified in the photomultiplier tube (PMT) and collected at the anode for the final signal



semiconductor diode detectors - HPGe detector

the absorbed γ-ray energy creates electron-hole pairs in a semiconductor which are separated in a strong electric field inside the semiconductor and produces a small signal



Comparison of γ-ray Spectra

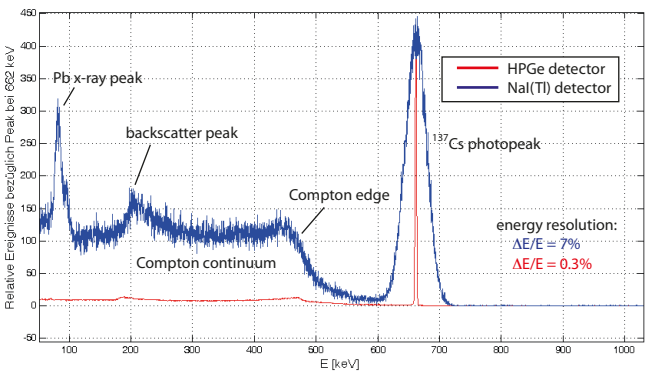


image sources: G. F. Knoll, Radiation Detection and Measurement, wikipedia.com, Canberra

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