ABSORPTION COEFFICIENT OF β AND γ-RAYS

Purpose

To measure total absorption coefficient and half-value width of β and γ-rays in aluminum and lead.
To practice least squares fitting method.

Background

Gamma ray absorption

γ-rays interact primarily with electrons of the matter. However, a gamma ray traversing matter does not gradually lose energy along its path but rather it interacts strongly at one point.

The three principal ways γ-rays lose energy are:

1. Photo absorption: γ + atom → ion + ejected electron
2. Compton scattering: γ + atom → γ' + ion + ejected electron
3. Pair production: γ + atom → atom + e^+ + e^-

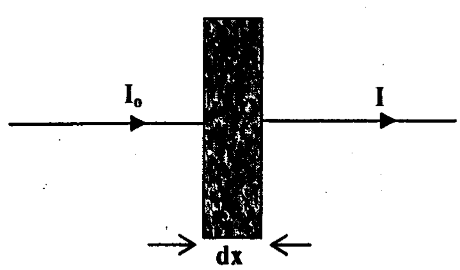
All of the gamma ray energy is transferred to the ejected electron in photo absorption. In Compton scattering some fraction of the incident gamma ray energy is transferred to the ejected electron. In pair production an electron-positron pair is produced.

At low gamma ray energies (≤ 1 MeV) photo absorption dominates. At intermediate energies (~ few MeV) Compton scattering dominates, and pair production is the dominant mechanism at high gamma ray energies.

Pair production will not occur if the gamma ray energy is less than 1.02 MeV. *Why?* (Think of conservation of energy, $e^{\pm}$ mass = 0.51 MeV).

If we have a beam of γ-rays of intensity I_0 incident on a material of thickness dx and an emerging beam of intensity I, the fraction of beam absorbed is proportional to dx.

$$\frac{dI}{I} = -\mu dx$$



Where $dI = I - I_0 < 0$ and μ is the total absorption coefficient of the material, which is the sum of three terms: $\mu = \mu_{photo} + \mu_{Compton} + \mu_{pair}$

By integrating we get $I(x) = I_0 e^{-\mu x}$

I(x) is the beam intensity after passing through a material of thickness x.

The absorption half-value width ($d_{1/2}$) is defined as: $I(d_{1/2}) = I_0/2$. Therefore,

$$d_{1/2} = \ln 2 / \mu$$

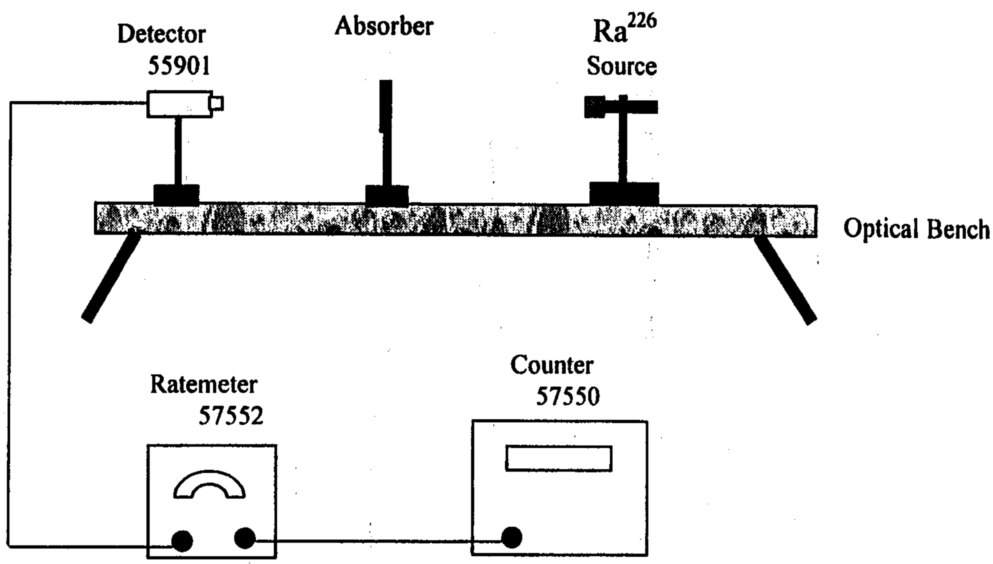
Beta absorption

Beta rays interact primarily with electrons of matter via the coulomb interaction leaving a trail of ions and excited atoms unlike gamma rays; a beta ray traversing matter usually loses energy gradually along its path. A difficulty in interpreting beta ray absorption data occurs because a beta source does not emit mono-energetic beam, but rather the emitted betas have a continuous energy spectrum ranging from zero up to a definite maximum energy. Therefore, unlike gamma rays, the intensity of beta rays does not decrease exactly exponentially with thickness of absorber. Further difficulties arise from the scattering of electrons.

The attenuation of a mixed radiation (β and γ for example), recorded as a function of absorber thickness by a detector sensitive to both radiation, can be described by a superposition of two exponential relations, each due to one component.

Procedure

1. Arrange the experimental setup as shown in the figure below and fix the source-detector distance such that you detect about 50 counts per second without absorber.



2. Record the count rate as a function of Al-absorber thickness.
3. Repeat the step 2 with Pb-absorber.
4. Be sure to take necessary steps to reduce random error in your measurements.

Analysis

Determine the absorption coefficient and half-value width of β-rays in Al and that of γ-rays in Al and Pb, using least squares fit to your data.

Additional Reading: Manufacturer's handout and Melissinos page 204-208.

Absorber #	Thickness (mg/cm2)
1	0
2	3
3	6.8
4	13.6
5	20.2
6	34.5
7	82.5
8	111.7
9	135.5
10	171.3
11	223.5
12	276.3
13	342.1
14	437.3
15	491.5
16	547.6
17	631.4
18	679.3
19	836.8
20	960.6
21	1008.2
22	1213.7
23	1372.5
24	1493.2
25	1605.4
A	926.4
B	1821.6
C	2648.1
D	4491.7
E	7143.6