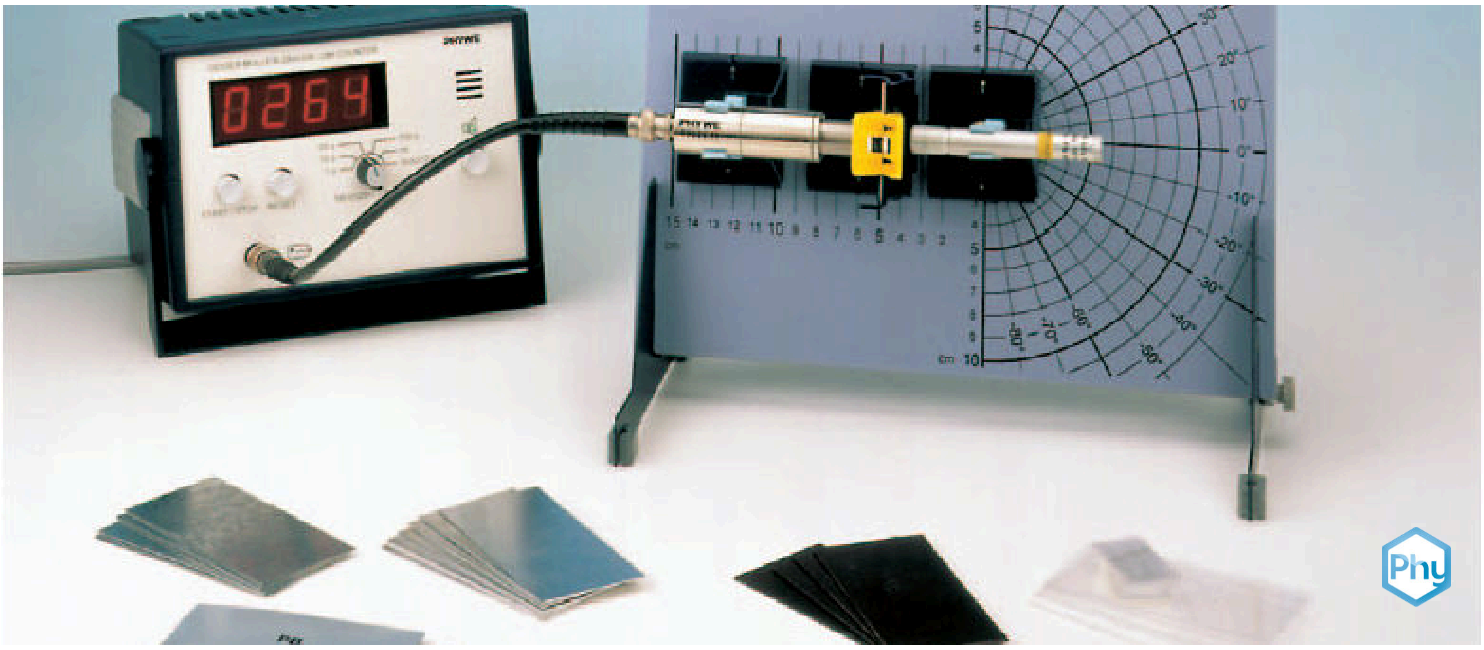
Electron absorption



Physics	Modern Physics	Nuclear & particle physics
Applied Science	Medicine	Nuclear Medicine

Difficulty level	Group size	Preparation time	Execution time
hard	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/5fb92f8e5f553800037ebb1d

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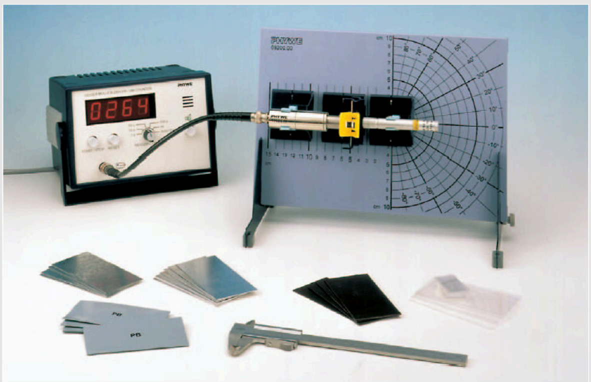
General information

Application



Setup

Electrons can be absorbed when interacting with a material. The specific absorbtion behaviour is dependent on the material and its thickness. By knowing this behaviour effective radiation protection can be manufactured.

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Other information (1/2)

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Prior knowledge

The prior knowledge for this experiment is found in the Theory section.

Main principle

The attenuation of an electron particle stream passing through a material layer depends both on the thickness of the layer and on the mass coverage, resp. the “mass per unit area”. It will be shown that the particle flux consisting of electrons of a particular energy distribution decreases with the “mass per unit area”. As electron source, a radioactive sample of $^{90}\mathrm{Sr}$ is used.

Other information (2/2)

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Learning objective

The goal of this experiment is to investigate the absorbtion behaviour of electrons.

Tasks

1. The β-counting rates are measured as a function of the absorber thickness using different absorbing materials such as aluminium (AL), glass (GL), hard paper (HP), and typing paper (TP).
2. The attenuation coefficients are evaluated for the four absorbing materials and plotted as a function of the density. .

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Theory

The attenuation of an electron particle stream by an absorbing material as a result of scattering and real absorption can be checked with a counter tube. The number of particles entering through the window of the counter tube per unit time, $\Delta \mathrm{I}$, is proportional to the counting rate indicated by the Geiger- Muller Counter. If $\Delta \mathrm{I}_0$ is the number of particles entering the counter tube per unit time in the absence of absorbing material, in the presence of absorbing material of thickness d, we expect to have, with $\Delta \mathrm{I}$ as the number of particles entering the counter tube per unit time

$$\Delta \mathrm{I} = \Delta \mathrm{I}_0 e^{-\mu \mathrm{d}} \qquad (1)$$

μ is the attenuation coefficient. It can be determined from Eq. (1): $\mu = \frac{\ln\left(\frac{\Delta \mathrm{I}_0}{\Delta \mathrm{I}}\right)}{\mathrm{d}}$ (2)

Plotting $\Delta \mathrm{I}$ semilogarithmically versus d makes it possible to measure the attenuation coefficient of the different materials used.

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Geiger-Müller Counter	13609-99	1
2	Geiger-Mueller counter tube, type B, BNC cable 50 cm	09005-00	1
3	Digital stopwatch, 24 h, 1/100 s and 1 s	24025-00	1
4	Vernier calliper stainless steel 0-160 mm, 1/20	03010-00	1
5	Base plate for radioactivity	09200-00	1
6	Counter tube holder on fixating magnet	09201-00	1
7	Plate holder on fixing magnet	09203-00	1
8	Source holder on fixing magnet	09202-00	1
9	Absorption plates for beta rays	09024-00	1
10	Cover glasses 22x40 mm, 100 p.	64688-00	1
11	Radioactive source Sr-90, 74 kBq	09047-53	1

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Setup and Procedure

Setup

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The plate holder which has a screw to fix the different absorbing materials is placed between the counter tube and the source holder. The distance between the front edge of the $^{90}\mathrm{Sr}$ source and the counter tube should be about 25 mm. The plastic cover of the counter tube has to be removed. The counter tube is connected to the Geiger-Muller Counter by means of a screened BNCcable. The Geiger-Muller Counter is used to count and total the pulses for different time intervals.

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Procedure

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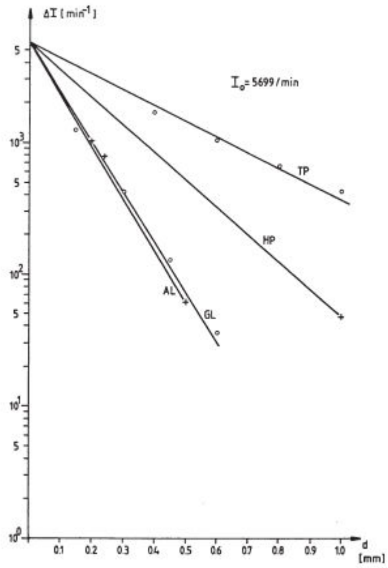
For statistical reasons, the time interval will have to vary between 60 seconds and 900 seconds.

First the counting rate is taken without an absorber. After that, the source is placed far away from the counter tube and the background radiation is measured over a period of at least 600 seconds.

Fig. 1: Counting rate ΔI as a function of absorber thickness.



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Evaluation

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Task 1

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d [mm]	Corrected count rate [1/min]	Material
0.15	1259	Glass
0.3	430	Glass
0.45	131	Glass
0.6	36	Glass
0.2	1021	Aluminium
0.24	786	Aluminium
0.5	61	Aluminium
0.4	1721	Typing Paper
0.6	1056	Typing Paper
0.8	672	Typing Paper
1.0	434	Typing Paper
1.0	48	Hard Paper

In Fig. 1 the counting rates are plotted semilogarithmically versus d. The graph consists of straight lines which proves the validity of Eq. (1). The counting rate without an absorbing material and with a distance of 25 mm between source and counter tube was found to be 5699 [1/min]. Here and in the following count rates, the background radiation of 21 counts/min has already been taken into account. The following values were used for the graph in Fig. 1:

Task 2

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From the slope of the straight lines in Fig. 1, the attenuation coefficients can be calculated using Eq. (2). The values obtained together with the densities of the absorbing materials are shown in the following table:

Fig. 3 shows the attenuation coefficient as a function of the density. The factor of proportionality between μ and ρ is the mass attenuation coefficient μ_m.

$\mu_\mathrm{m} = \frac{\mu}{\rho} = 35.4 \pm 3.4\,\mathrm{cm}^2/\mathrm{g}$ (3)

	μ [1/mm]	ρ $[\mathrm{g}/\mathrm{cm}^3]$
Typing Paper	2.71	0.852
Hard Paper	4.78	1.39
Glass	8.75	2.37
Aluminium	9.15	2.70

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Task 2 (part 2)

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For a particuluar energy distribution of the particles considered, e. g. for particular β^- emitting source, μ_m is a constant for all absorbing materials. In the literature pertaining to this comples* μ can be calculated using the empirical formula

$$\mu_\mathrm{m} = \frac{22\ \mathrm{cm}^2/\mathrm{g}}{\mathrm{W}_\mathrm{m}^{\pm 333}/\mathrm{MeV}} \mathrm{W}_\mathrm{m} > 0.5\,\mathrm{MeV}$$

where W_m is the maximum energy of the particles. For the electrons of $^{85}\mathrm{Kr}$, W_m is equal to 0.7 MeV. This leads to the value

$$\mu_\mathrm{m} = 35.4\,\mathrm{cm}^2/\mathrm{g}$$

Task 2 (part 3)

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Using Eq. (3) we can rewrite Eq. (1) in the following way

$$\Delta\mathrm{I} = \Delta\mathrm{I}_0 e^{-\mu_\mathrm{m}\cdot\rho\cdot\mathrm{d}} \quad (4)$$

or

$$\Delta\mathrm{I} = \Delta\mathrm{I}_0 e^{-\mu_\mathrm{m}\cdot\mathrm{d}^\mathrm{H}} \quad (5)$$

The product $\mathrm{m}^\mathrm{H} = \rho\cdot\mathrm{d}$ within Eq. (5) is the mass coverage, resp. the “mass per unit area” and obviously the quantity which determines the attenuation of the particle stream when it passes through the material layer of thickness d.

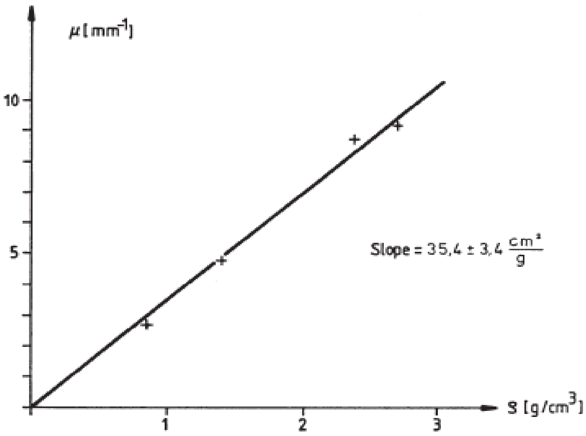

Fig. 2: Attenuation coefficient as a function of the density.

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