

### Related topics

Density, counter tube, radioactive decay, attenuation coefficient, mass coverage.

### Principle and task

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  $\text{Sr}^{90}$  is used.

### Equipment

Radioactive source, Sr-90, 74 kBq	09047.53	1
Geiger-Müller Counter	13606.93	1
Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l 750 mm	07542.11	1
Stopwatch, digital, 1/100 sec.	03071.01	1
Base plate for radioactivity	09200.00	1
Supports f. base 09200.00, 2 pcs	09200.01	1
Counter tube holder on fix. magn.	09201.00	1
Plate holder on fixing magnet	09203.00	1
Source holder on fixing magnet	09202.00	1
Vernier caliper	03010.00	1
Absorption plates f. beta-rays	09024.00	1
Cover glasses 22×40 mm, 50 p	64688.00	1

### Problems

1. The  $\beta$ -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.

### Set-up and procedure

The experimental set-up is shown in Fig. 1. 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  $\text{Sr}^{90}$  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-Müller Counter by means of a screened BNC-cable. The Geiger-Müller Counter is used to count and total the pulses for different time intervals.

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: Experimental set-up: Electron absorption.

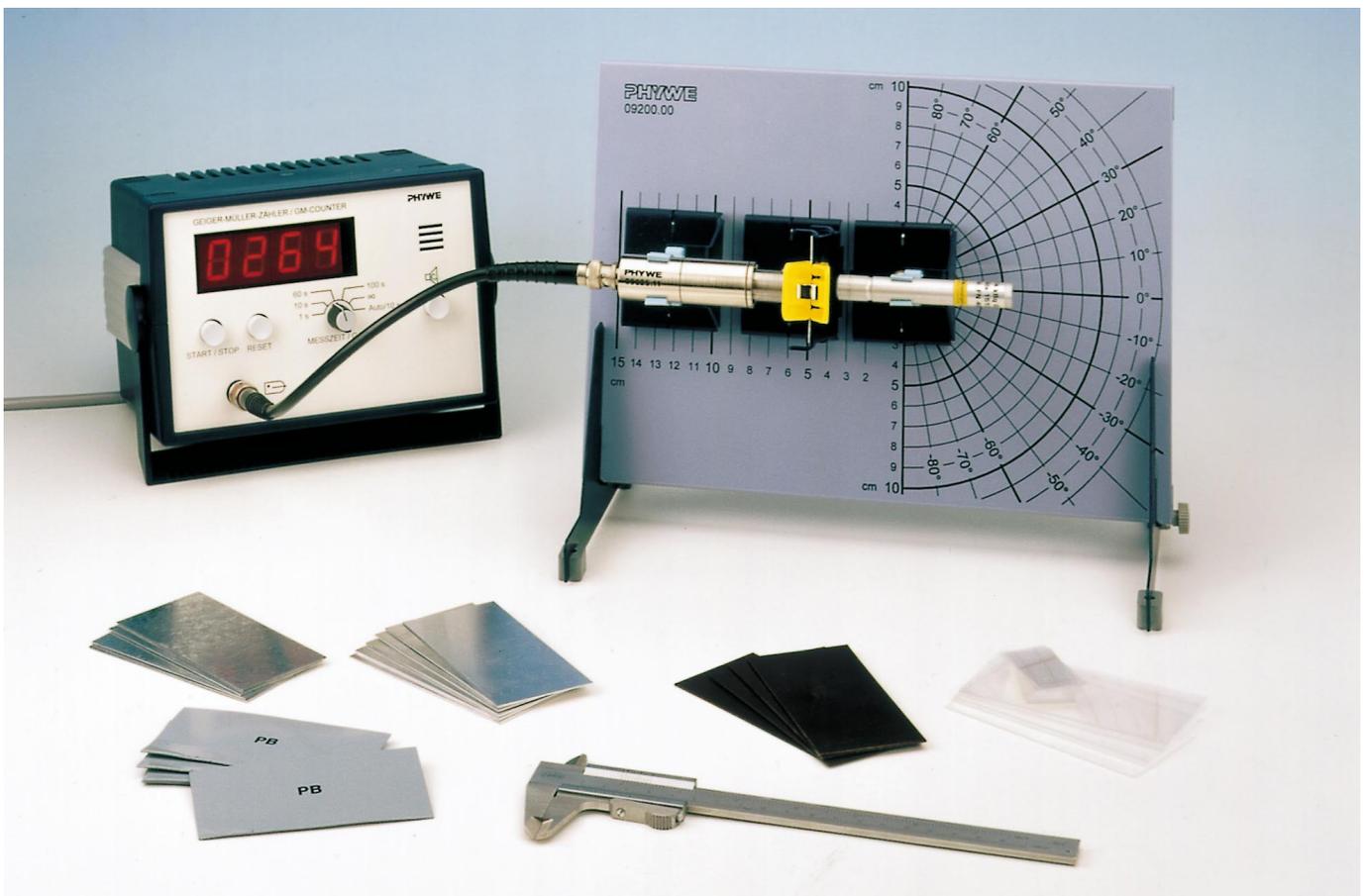
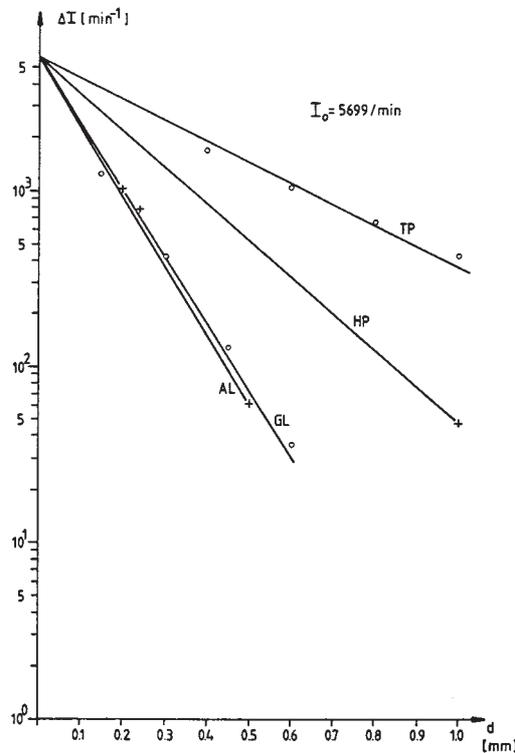


Fig. 2: Counting rate  $\Delta I$  as a function of absorber thickness.



$d$ [mm]	corrected count rate [min <sup>-1</sup> ]	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)

2. From the slope of the straight lines in Fig. 2, 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:

	$\mu$ [mm <sup>-1</sup> ]	$\rho$ [gr/cm <sup>3</sup> ]
Typing Paper	2.71	0.852
Hard Paper	4.78	1.39
Glass	8.75	2.37
Aluminium	9.15	2.70

### Theory and evaluation

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,  $\Delta I$ , is proportional to the counting rate indicated by the Geiger-Müller Counter. If  $\Delta I_0$  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  $\Delta I$  as the number of particles entering the counter tube per unit time

$$\Delta I = \Delta I_0 e^{-\mu d} \quad (1)$$

$\mu$  is the attenuation coefficient. It can be determined from Eq. (1):

$$\mu = \frac{\ln \frac{\Delta I_0}{\Delta I}}{d} \quad (2)$$

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

1. In Fig. 2 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 [min<sup>-1</sup>]. 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. 2:

Fig. 3 shows the attenuation coefficient as a function of the density. The factor of proportionality between  $\mu$  and  $\rho$  is the mass attenuation coefficient  $\mu_m$ .

$$\mu_m = \frac{\mu}{\rho} = 35.4 \pm 3.4 \frac{\text{cm}^2}{\text{g}} \quad (3)$$

For a particular energy distribution of the particles considered, e.g. for particular  $\beta^-$  emitting source,  $\mu_m$  is a constant for all absorbing materials. In the literature pertaining to this complex\*  $\mu_m$  can be calculated using the empirical formula

$$\mu_m = \frac{22 \frac{\text{cm}^2}{\text{g}}}{W_m^{1.333} / \text{MeV}} \quad W_m > 0.5 \text{ MeV}$$

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

$$\mu_m = 35.4 \frac{\text{cm}^2}{\text{g}}$$

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

$$\Delta I = \Delta I_0 e^{-\mu_m \cdot \rho \cdot d} \quad (4)$$

or

$$\Delta I = \Delta I_0 e^{-\mu_m \cdot m''} \quad (4)$$

The product  $m'' = \rho \cdot d$  within Eq. (4) 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  $d$ .

\* Kuchling, Taschenbuch der Physik, Verlag Harri Deutsch, Thun, Frankfurt/Main

Fig. 3: Attenuation coefficient as a function of the density.

