Absorption of γ-quantums and their dependence on the material density

LEP 5.2.43

Related topics

Radioactive radiation, half-value thickness, absorption coefficient.

Principle and task

The γ-quantums emitted by a radioactive γ-radiator (Co-60) are absorbed into solid matter. The weakening of the quantum current connected to it depends on the radiated path or thickness level of a layer of matter in the radiation field on one hand, and, on the other hand, on the density of the radiated matter.

The particle current decreases exponentially with the thickness of the layer, the weakening coefficient μ increases almot proportionally to the density ρ of the absorption material.

Equipment

Counter tube, type A, BNC	09025.11	1
Screened cable, BNC, l 750 mm	07542.11	1
Radioactive source Co-60, 74 kBq	09047.54	1
Base plate	11600.00	1
Magnetic base for 09053.88	09053.01	3
Counter tube holder for 09053.01	09053.02	1
Source holder for 09053.01	09053.04	1
Plate holder for 09053.01	09053.05	1
Absorption material, lead	09029.01	1
Absorption material, iron	09029.02	1
Absorption material, aluminium	09029.03	1
Absorption material, Plexiglas	09029.04	1
Absorption material, concrete	09029.05	1
COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Counter tube module	12106.00	1
Softw. COBRA Radioactivity	14256.51	1

Set-up and procedure

— The experiment is set-up as shown in Fig. 1. The distance between the front edge of the radiating pin and the counter tube window is about 7 cm.
— Load the programme “Radiactivity” (Radio 1) and start it.
— Measure background noise in the absence of the preparation:
<measure>, <zero effect>, <measure>, “Time interval approx. 500 s”, <Ok>
— Parameter adjustments (<measure>, <parameters>):

Type of measurement	manually controlled measuring sequence
Zero effect	substrat
Measuring time	60 s
Number of measurments	7

Fig. 1: Experimental set-up: Absorption of γ-quantums and their dependence on the material density.

— Activate the measurement process using <measure>, <start>, <Ok>

— First bring the preparation to a distance of approx. 7 cm from the counter tube and make the following adjustments in the menu window:
"Unit cm", "Step width Δx: 0", (at first there is no absorbing material between the preparation and the counter tube, then press <Ok> in the dialogue window.

— The lead plates are placed individually or several together in the plate holder. (If the layer thickness is more than 3 cm you do not have to use the plate holder and the plates can be placed directly on the magnetic base). In this way, the thickness of layer d beginning at d = 0.2 cm can be increased step by step. Press "Return" after every individual measurement, put a new absorbing plate between the counter tube and the preparation and enter the new thickness level in the dialogue window under "x-Value" and then click <Ok>.
The following thickness layers (in cm) are recommended: 0.1; 0.5; 1.0; 2.0; 3.0; 4.0.

— After completing the measurement series select <ESC> if required.

— The graphic representation can be obtained using: <F7>, <graphics>, <dependece>, "$N/\Delta t$", "Logarithmic", "sec", "substract", " ", <Ok>.

— Linear regression calculation:
<graphics>, <straight compensating line>, <Ok> (cf. Fig. 2). Calculation of the half-value thickness: <edit>, <calculation>, Window "2", <Ok>

— In the following way, the level of absorption of different absorption materials of various thicknesses can be determined

Lead	d = 0	0.1	0.5	1.0	2.0	3.0 cm
Iron	d = 0	0.5	1.0	2.0	3.0	4.0 cm
Aluminium	d = 0	0.5	1.0	2.0	3.0	4.0 cm
Plexiglass®	d = 0	0.5	1.0	2.0	3.0	4.0 cm
Concrete	d = 0	1.0	2.0	3.0	4.0 cm	

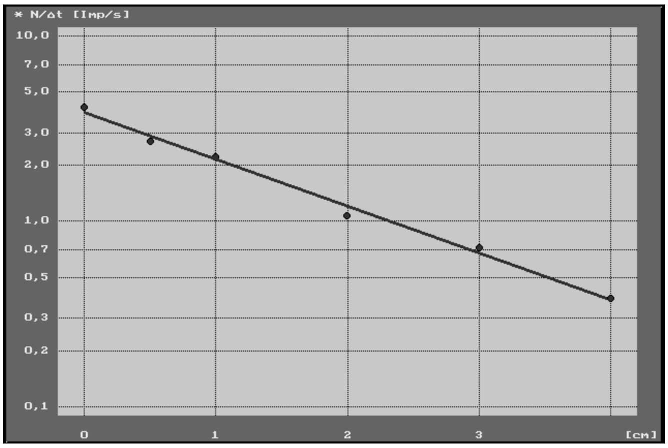

Fig. 2: Logarithmed counting rate (Co-60) as dependent on the absorbing film thickness (Pb)

Theory and evaluation

— Fig. 2 shows the counting rate in a logarithmic application as dependent on the absorption thickness. The straight line drawn confirms the approximate validity of the exponential decrease in the counting rate as dependent on the thickness layer.

— The γ-quantums emitted from the preparation (Co-60) are absorbed into the lead layer according to the layer thickness d in different ways. The qunatum current I is weakened by the absorption layer as compared with the quantum current I_0 in the air. The weakening of the quantum current occurs according to the absorption law; the quantum current I almost decreases exponentially as the thickness of layer d increases:

$$I = I_0 \cdot e^{-\mu d}$$

The exiting quantum current I_0 is weakened by half at a very specific thickness layer d_H:

$$\frac{1}{2} I_0 = I_0 \cdot e^{-d_H}$$

It follows from this that the half-value thickness d is determined using the weakening coefficient μ:

$$d_H = \frac{\ln 2}{\mu}$$

or

$$\mu = \frac{\ln 2}{d_H} .$$

The weakening coefficient μ characterises the absorption behaviour of the material towards the γ-quantums.

— To find out the weakening coefficient μ:
According to the logarithmic representation as shown in Fig. 2: <edit>, <calculation>.
The half value thickness in this measurement example is d_H = 1.4 ± 0.2 cm and the weakening coefficient s μ = 0.49 cm^{-1}.

— In the second part of the experiment, layers of matter of a different thickness d and varying density ρ are arranged in the radiating field between the γ-radiator Co-60 and the counter tube. The half-value thicknesses for iron, aluminium, plexiglass and concrete are determined in the same manner as the evaluation described before and the weakening coefficient is calculated.

Material	Density g/cm^3	Half value thickness d_H in cm	weakening coefficient μ in cm^{-1}
Lead	11.11	1.54 (17)	0.45
Iron	7.68	2.3 (4)	0.30
Aluminium	2.70	7 (3)	0.09
Concrete	1.87	6(3)	0.12
Plexiglass®	1.19	35 (82)	0.02

The weakening coefficient μ increases in an approximate proportion to the density ρ of the absorbing material:

$$\mu = \mu_m \cdot \rho$$

The proportionality factor of the mass weakening coefficient μ_m is a result of the increase in the straight line shown in Fig. 3:

$$\mu_m = \frac{\mu}{\rho} = 0.04 \frac{cm^2}{g} .$$

The γ-quantums emitted by the γ-preparation are absorbed according to the density of the material when the matter is traversed. The current of γ-quantums is weakened by a layer of material with a thickness layer d according to the weakening law

$$I = I_0 \cdot e^{-\mu d}$$

In this case μ is the characteristic weakening coefficient (depending on the energy of the γ-radiation).
The weakening coefficient depends on the density ρ of the material:

$$\mu = \mu_m \cdot \rho$$

The mass weakening coefficient μ_m is approximately the same size for all materials (when the energy of the γ-quantums is consistent). This why the weakening law is appropriately written in the form

$$I = I_0 \cdot e^{-\mu_m m''}$$

where

$$m'' = \rho \cdot d.$$

The mass covereing m'' indicates which mass has an absorption layer per surface unit. The mass covering m'' is the required size for the weakeing of a γ-current.

Note

— The counting rates measured depend on the preparation used and the age of the sample.
— The weakening coefficients μ also depend on the energy of the γ-quantums emitted which is relatively high in the case of Co-60 (hard γ-radiation). When the energy is low (soft γ-radiation) the values for the weakening coefficients are different.

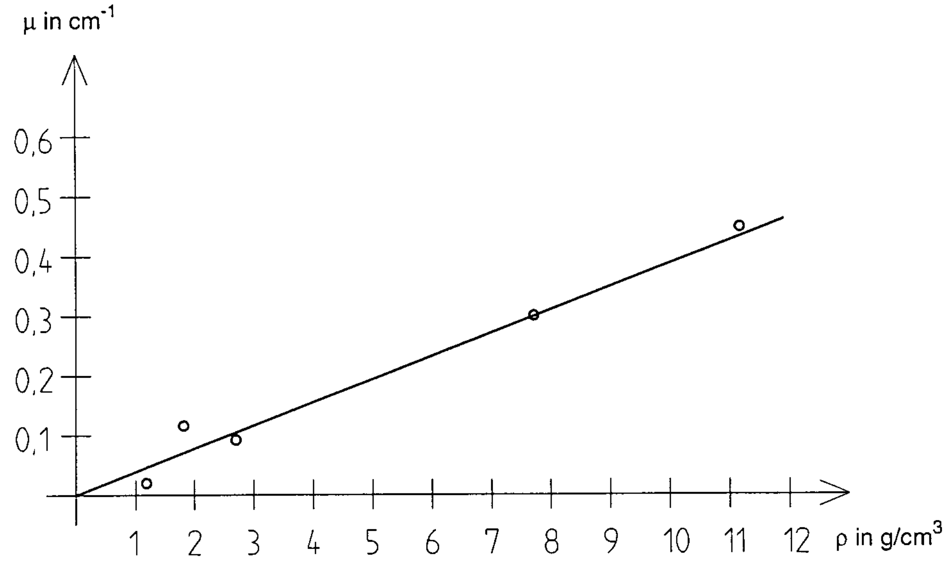

Fig. 3