Determining the thickness of the coating layer

(Item No.: P1315900)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
ILIAS	Physik	Klasse 10-13	Aufbau der Materie	Kernphysik

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	1 Hour	2 Hours	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

Task and equipment

Introduction

Metallic surfaces are normally given a coating of paint or lacquer to protect them from corrosion or to improve their appearance. In such two-layered systems if the absorption behavior of the two substances shows large differences, the method of the back scattering of β-rays is especially suitable for measuring the thickness of the coating. β-rays are deviated from their direction in the coulomb field of the atoms, whereby a part of their energy gets scattered. The back scattering depends on the energy of the radiation, the atomic number and the strength of the material used. If a back scattering plate is coated with a layer of another material having a lower density or low atomic number, then the β-rays which have already lost a part of their energy through the back scattering process, get absorbed. The back scattering thus approaches a saturation value with increasing coating thickness. This value is reached, when the thickness of the coating is approximately the same as the range of the β-rays in this material.

This experiment will show that the count rate of the back scattered β-rays gets reduced, when thin layers of aluminum or paper are coated as back scattering material on a lead plate. With the help of the dependence of the backscattered intensity on the coating thickness of the covering material, unknown coating thickness can be determined.

Fig. 1: Experimental setup

Equipment

Position No.	Material	Order No.	Quantity
1	Support clamp for small case	02043-10	1
2	Clamp on holder	02164-00	1
3	Support rod,stainl.steel, 100mm	02030-00	1
4	Counter tube holder on fixating magnet	09201-00	1
5	Source holder on fixing magnet	09202-00	1
6	Plate holder on fixing magnet	09203-00	1
7	Geiger-Mueller counter tube, 15 mm (type B)	09005-00	1
8	Geiger-Müller-Counter	13606-99	1
9	Demo Physics board with stand	02150-00	1
10	Absorption material f.student exp	09014-03	1
11		undefined	1
12	Vernier calliper stainless steel 0-160 mm, 1/20	03010-00	1

Set-up and procedure

Set-up

The experiment is set up as per Fig.1.

- Place the radiation source Sr-90 in the source holder and the counter tube without the protective cap in the counter tube holder; set these on the demo board as shown in Fig. 1 such that the opening for the radiation and the counter tube window have a downward inclination and their axes make an angle of about 90°.
- Keep the plate holder on the demo board such that it is at a distance of 2 cm from the radiation source and the counter tube.

Fig.1

Procedure

Select a measurement time of 60 s.

Experiment 1

- Determine the count rate Z_0 (without the back-scattering plate).
- Place 1 mm plates, each made of Plexiglas, hard paper, aluminum, iron and lead one after the other on the plate holder, determine the count rates Z and enter the values in Table 1 ("Results").

Experiment 2

- Place aluminum plates of the thicknesses given in Table 2 one after the other on the lead plate and determine the count rate Z for each; enter the count rate difference (Z-Z_0) in Table 2.
- Place an aluminum plate of unknown thickness and determine the count rate and the count rate difference.
- Make 10 paper strips having the dimensions 50 mm x 100 mm from index cards and determine their thickness with the help of a slide caliper for reducing the measurement error.
- Determine the back-scattering rates for 2, 4, 6, 8 and 10 paper strips and note down the count rate difference.
- Place another paper strip of unknown thickness made from a different material on the lead plate, determine the back-scattering rate and note down the count rate difference.
- After concluding the measurements, replace the radiation source back in the container and place the protective cap back on the counter tube.

Results and evaluation

Results

Result: $Z_0 = 399\ Imp\ /\ 60\ s$

Table 1

Back scattering material	$\frac{Z}{Imp/60\ s}$
Plexiglas	509
Hard paper	526
Aluminium	751
Steel	1021
Lead	1480

Table 2

Material Aluminium			Material Paper Strength of a strip d = 0.25 mm		
Coating thickness d /mm	$\frac{Z}{Imp/60\ s}$	$\frac{Z - Z_0}{Imp/60\ s}$	$\frac{Number}{n}$	$\frac{Z}{Imp/60\ s}$	$\frac{Z - Z_0}{Imp/60\ s}$
0	1489	1090	0	1566	1167
0,3	1108	709	2	1258	859
0,5	918	519	4	981	582
0,8	830	431	6	858	459
1	793	394	8	757	358
unknown	1050	651	10	716	317
			unknown	1150	751

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Evaluation

Experiment 1

Even without the back-scattering material the β-particles reach the counter tube directly from the radiation source or else after being scattered from the demo-board and thereby cause the scattering rate Z_0, which overlaps the actual back-scattering rate. Also the plate holder causes a backscattering rate.
The back-scattering rates Z of hard paper, Plexiglas and aluminum are only marginally above the rate Z_0. Hence, very less back-scattering of β-particles takes place from materials with low density and atomic number.
The highest back-scattering rate is produced by lead because of its high density of ρ = 11.3 g/cm^3 and its high atomic number of 82.

Experiment 2

The dependence of the back-scattering rates on the thickness of the coated layers has been displayed graphically in Fig. 2 under consideration of the count rate Z_0 = 399 Imp/60 s measured without the back-scattering material. It can be seen from this display, that the back-scattering rates reduce at first very steeply and then only gradually with increasing thickness of the back-scattering material. The coating thickness can be read with less accuracy in this saturation area.
The unknown coating thickness can be read from the graphic display. One gets a coating thickness of d = 0.35 mm for aluminum with a corrected count rate of 651 Imp/60 s.
For the unknown thickness of the paper strip one gets a value of 2.8 with the corrected count rate of 751 Imp/60 s. This results in a coating thickness of d = 2.8 x 0.25 mm = 0.7 mm
Note: When using a radiation source with a lower energy of the β-rays, the saturation range is reached at lower coating thicknesses. The measurement method can be adapted to different measurement ranges by selecting a suitable radiation source.

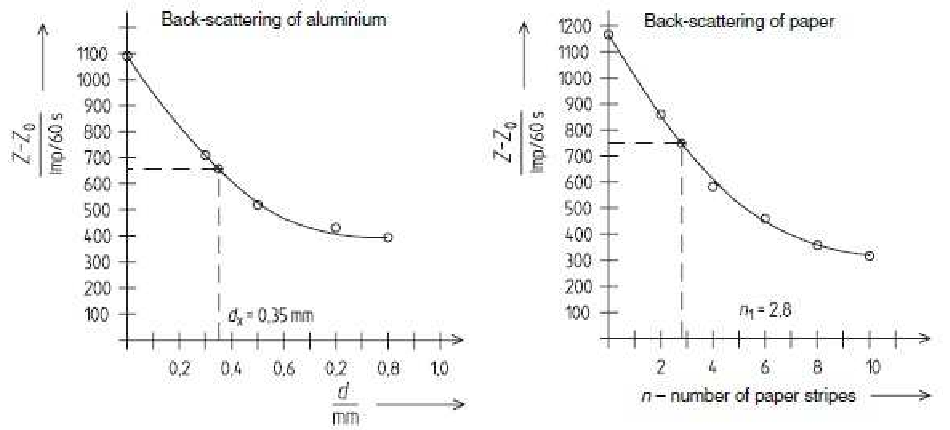

Fig.2