Experiment 5

Absorption of Beta Particles in Aluminium and Perspex

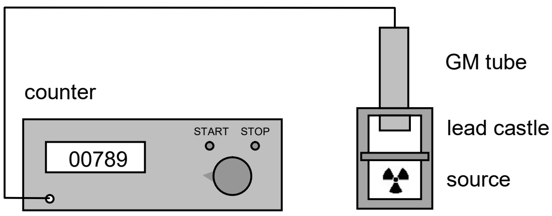
First read the introduction at experiment 5 in the booklet *ISP Experiments* about absorption of β radiation.

Aim

- To determine the relation between thickness of the absorbing material and intensity of the transmitted β radiation.
- To measure the range and the universal range of β particles in aluminium and perspex.
- To measure the maximum energy of β particles, emitted by a source of strontium-90.

Set-up

The set-up consists of a Geiger-Müller tube mounted in a 'lead castle', a pulse counter, and a source of strontium-90 (^{90}Sr). The counter can be set to an automatic measuring time of 10 s or to 'continuous'. In the latter case, after starting the counter will continue counting until the stop button is pressed. For measuring time, then use a stopwatch.
Sheets of aluminium and perspex can be inserted between the GM tube and the source in the lead castle. The available sheets of aluminium are of different thickness. The thickness of the absorbing aluminium can be varied further by combining sheets of different thickness. The available sheets of perspex are all of the same thickness. Therefore, the thickness of the absorbing perspex can only be varied by combining sheets.



With the equipment set-up, the intensity *I* (in pulses per unit of time) of the transmitted β radiation can be measured as a function of the thickness *d* of the absorbing material.

Research Question

- Draw up a research question fitting the aim and equipment set-up of this experiment.

Hypothesis

- Draw up an argued hypothesis about the relation between the intensity *I* of the transmitted β radiation and the thickness d of the absorbing material, for aluminium as well as for perspex.
- Give this hypothesis also in the form of a sketch of the relation between these quantities in an *I*,*d*-graph.

Plan of Work

- Draw up a plan of work for the investigation with the given equipment set-up.
- In this plan of work, indicate how you will vary which quantities in order to be able to check your hypothesis.
- Indicate how you will correct your measurements for the background radiation.
- Prepare an (empty) table for recording your measurements.
- Indicate whether the experiment will contribute to the radiation dose you receive during the laboratory session. And, if so: how you can take care that this radiation dose stays as low as possible.
- Discuss your research question, hypothesis and corresponding plan of work with your teacher or the school's laboratory technician.
- If necessary, review your research question, hypothesis and/or plan of work.

Investigation

- Carry out the investigation according to your plan of work. During the laboratory session, take care of an adequate radiation protection.

Data Processing

- Process your measurements in order to check your hypothesis, and to answer your research question. The box below gives some instructions for such data processing.

Instructions

● Plot your measurements in a graph.

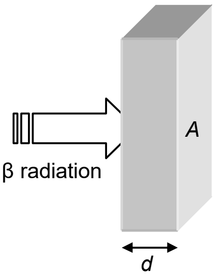
> From the graph, determine the range *R* of β particles in aluminium and perspex.

● Information about an accurate way of determining quantities from a graph on single logarithmic graph paper can be found in the booklet *ISP Experiments*.

> Plot your measurements in a graph on single logarithmic graph paper. Plot the intensity *I* (not corrected for the background radiation) on the logarithmic axis (vertical) and the thickness *d* on the linear axis (horizontal). Use the same graph for aluminium as well as perspex. In the graph, also draw a horizontal line representing the intensity of the background radiation.

When using single logarithmic graph paper, the first part of the graph will be linear. The second part of the graph will show some abnormalities because of the measured ‘braking radiation’ (see the booklet *ISP Experiments*, list of concepts) and statistical measuring errors. Disregard these abnormalities when drawing the graph.

> From the graph, determine the range *R* of β particles in aluminium and perspex by extrapolating the linear part of the graph to the line representing the intensity of the background radiation.



● Plot your measurements – again on single logarithmic graph paper, and again with the intensity *I* not corrected for the background radiation – for aluminium and perspex in the same graph, but now plot the mass per unit of area *m*/*A* instead of the thickness *d* on the linear axis. This mass per unit of area is given by (see also the figure on the left):

$$\frac{m}{A} = \frac{\rho \cdot V}{A} = \frac{\rho \cdot A \cdot d}{A} = \rho \cdot d$$

In this formula, ρ is the density of the material: 2700 mg/cm^3 for aluminium and 1200 mg/cm^3 for perspex. With the density ρ in the unit mg/cm^3 and the thickness *d* in the unit cm, the mass per unit of area *m*/*A* will have the unit mg/cm^2.

> What do you notice when both graphs have been drawn?

● Depending on their energy, β particles travel a certain distance in which they completely transfer their energy to the absorbing material. This distance is called the range *R*. The value of this range is different for each material. However, when we look at the mass per unit of area *m*/*A* (instead of the thickness *d*) of the absorbing material we will see that for roughly the same value of *m*/*A* each material has fully absorbed the β particles. We call this value of *m*/*A* the *universal range* R_u. See also the background information on the ISP website (in Dutch): stralenpracticum.nl > students > background information > universal range. This background information is also available as an information sheet (in English) at the equipment set-up.

> From the graph, determine the universal range R_u of β particles by extrapolating the linear part of the graph to the line representing the intensity of the background radiation.

● From the universal range R_u and the density ρ of a material, the range *R* of β particles in the material can be calculated.

> Calculate the range *R* of β particles in aluminium, perspex and the human body, and compare the results – as far as possible – with earlier measurement results.

● The universal range R_u in matter depends on the maximum energy *E* of the β particles. The relation between both quantities is given by the following formula: R_u (in mg/cm^2) = 500·*E* (in MeV).

> Calculate the maximum energy of the β particles emitted by the source of ^{90}Sr.

Extra question

Calculate the range of beta-particles in the human body (ρ=1 g/cm^3). The magnitude of this range has consequences for the applications of beta radiation in the medical world. What can you say about these consequences?

Report

● Write a report about this investigation. This report presents your *research question*, *hypothesis*, (processed) *measurements* and *conclusion* about the hypothesis being confirmed or not.