**Experiment 13**

# Qualitative Identification of Radioactive Sources

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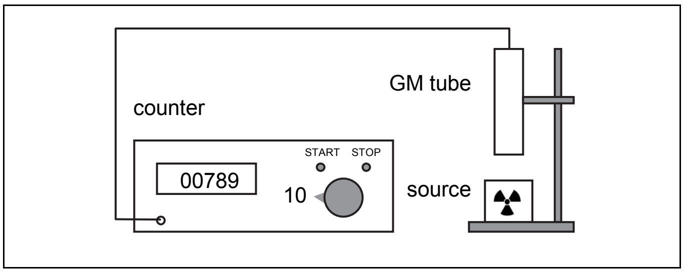
## Aim

To identify the kinds of radiation emitted by unknown radioactive sources.

## Set-up

The set-up consists of a Geiger-Müller tube, a pulse counter, some absorbers (sheets of paper, 4 mm aluminium and 4 mm lead) and three unknown radioactive sources.




Read the introduction on page 16 of the booklet *ISP Experiments* about the penetrating power of the different kinds of radiation.

## Theory

A radioactive source can emit three kinds of radiation: α, β and/or γ radiation. These kinds of radiation can be identified with the help of their penetrating power.

**Alpha radiation** consists of particles: fast-moving helium nuclei. This kind of radiation can be stopped easily. Because of their relatively large size, α particles do not have a large penetrating power. A sheet of paper or a few cm of air will absorb the α particles. However, β and γ radiation are hardly absorbed by the air between the radioactive source and the GM tube.

**Beta radiation** also consists of particles, like α radiation, but these fast-moving electrons have a larger penetrating power as they are about 7300 times as small. A sheet of aluminium of about 4 mm thickness will absorb the β particles (and, of course, the α particles as well).

**Gamma radiation** is electromagnetic radiation with a very large penetrating power. No material will fully absorb this kind of radiation. The effect of an absorber will be no more than a weakening of the incident γ radiation. The degree of weakening is expressed by the half-value thickness of the absorbing material. This is the thickness of the material when the intensity of the transmitted radiation is half the intensity of the incident radiation. For the γ radiation from the sources used in this experiment, the half-value thickness of lead is 1.2 cm. A sheet of lead of 4 mm thickness will thus transmit more than half of the incident radiation.
However, the half-value thickness of lead depends on the energy of the incident γ radiation: for low-energetic γ radiation the half-value thickness is smaller than for high-energetic γ radiation.

By measuring the intensity of the transmitted radiation (in pulses per 10 s) when using air, paper, aluminium and lead, respectively, as an absorber, we can identify the kinds of radiation emitted by the radioactive sources.

## Measurements

**1** Measure the intensity $I_b$ of the background radiation (in pulses per 10 s) three times, and record your measurements in the table below. Make sure that the three radioactive sources are at approximately 1 m distance from the GM tube. Calculate the average intensity $I_{b,avr}$ of the background radiation (in pulses per 10 s), and record the result in the table below.

| | | | | | |
|---|---|---|---|---|---|
| $I_b$ (pulses/10s) | | | | $I_{b,avr}$ (pulses/10s) | |

**2** Remove the lid from source A, and position the source underneath the GM tube (leave the other sources at approximately 1 m distance from the GM tube). Measure the intensity $I$ of the transmitted radiation (in pulses per 10 s) when using each of the four absorbers indicated in the table on the other side of this worksheet. Record your measurements in the table. Put the lid on the source and position the source at 1 m distance.

3 Repeat these measurements with sources B and C.

| | air | paper | 4 mm aluminium | 4 mm lead | kind(s) of radiation |
|---|---|---|---|---|---|
| source A | | | | | |
| source B | | | | | |
| source C | | | | | |

**Assignments**

1 Use the data from the table to identify the kind(s) of radiation emitted by each of the three sources, and record your conclusions in the table above. In doing this, remember that a radioactive substance can decay into another substance that is also radioactive: the so-called daughter product. So, this daughter product will also emit radiation, but this can be a different kind of radiation as emitted during the first decay. Therefore, a radioactive source can simultaneously emit different kinds of radiation.

Radioactivity may be harmful to man, depending on the amount of radiation absorbed in the body. The equivalent dose per unit of time is usually expressed in microsievert per hour (μSv/h) or millisievert per year (mSv/y). In the Netherlands the equivalent dose from the natural background radiation is about 1.8 mSv/y (see page 38 in the booklet *ISP Experiments*). When working with radioactive sources, the legally acceptable equivalent dose is 5 mSv/y or 2.5 μSv/h, assuming 50 working weeks of 40 hours each.

2 The legally acceptable equivalent dose of 2.5 μSv/h is equivalent to an intensity of 12 pulses per second in this experiment. If you had to use your measurements in this experiment to shield each of the sources in an acceptable way, which material would you use and how thick would it be? Record your conclusions in the table below. In drawing your conclusions, remember the importance of keeping the shielding as light and thin as possible. If necessary, use the known half-value thickness of lead for the $\gamma$ radiation emitted by the sources in this experiment: $d_{1/2}$ = 1.2 cm.

| | shielding material | thickness (mm) |
|---|---|---|
| source A | | |
| source B | | |
| source C | | |

3 A school technician wants to dispose of a smoke detector containing a source of americium-241 ($^{241}$Am). The radiation level measured with a Geiger-Müller tube on the outside of the detector is not higher than the background radiation level. The radioactive isotope Am-241 has a half-life $t_{1/2}$ of 432 y. The energies of the emitted α and $\gamma$ radiation are: $E_{\alpha}$ = 5.5 MeV, $E_{\gamma 1}$ = 27 keV and $E_{\gamma 2}$ = 60 keV (1 eV = $1.6 \cdot 10^{-19}$ J).
Is it allowed to throw the detector into the garbage bin? Explain your answer.

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**Note**

Shielding a radioactive source with an absorber is just one of the ways to reduce the radiation dose. Other ways are increasing the distance to the source (see Experiment 8 about the inverse square law), and decreasing the exposure time.