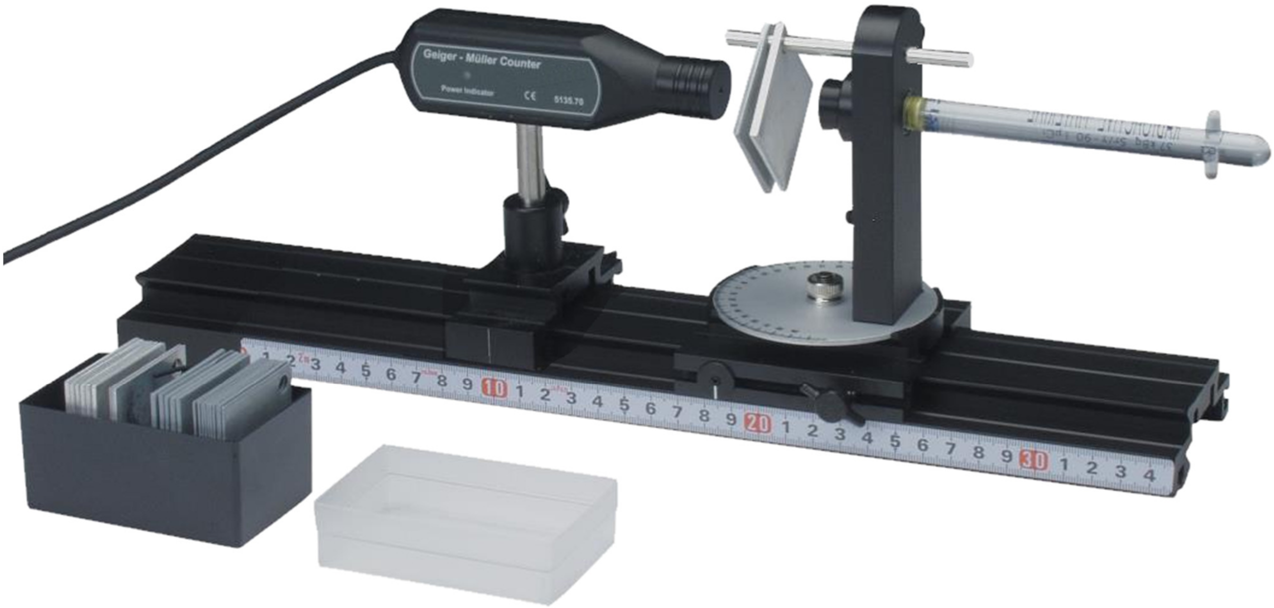
Number	138410-EN	*Topic*	Radioactivity				
Version	2017-08-25 / HS	*Type*	demo / student exercise	*Suggested for*	grade 9 - 10	*p.*	1/4



Objective

To investigate the radiation from the three sources concerning the ability to penetrate matter.
To observe the natural background radiation and that radiation arrives at irregular intervals.

Principle

For each source, counts are accumulated in 10-seconds intervals. (The distance to the sources is so small that absorption in the air is negligible.)

Equipment

(See detailed list on last page)

Complete set of Risø sources*
Geiger-Müller tube
GM counter
Experiment bench
Paper

Alpha, *beta* and *gamma* are three (small) letters from the Greek alphabet. They look like this:

α β γ

* Other types of sources can be used. (See p. 4.)

Work carefully

Follow your teacher’s instruction for working with radioactive sources.

Keep a suitable distance to the sources
Limit the time you need to handle or stay close to the sources
Consumption of food or beverages is not allowed in the room while the sources are used

Sources with a handle should only be manipulated using the end that is furthest away from the source.

Note: **Don’t** use e.g. a finger between the source and the GM tube if you want to investigate something like living tissue. Use a slice of salami or similar (and throw it out afterwards).

When not in use, the sources should be replaced to their storage cupboard immediately.

Setup

Place the source holder and the rider for the GM tube on the bench as shown on p. 1. Place the GM tube as shown and tighten the finger screw.
Remove the protective cap from the GM tube.

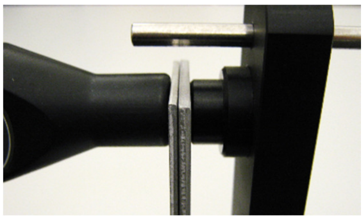
Reduce the distance so that only approx. 5 mm remains between the GM tube and the source holder. Note: If the beta source is so intense that the counter overflows, increase the distance – but only for that source.

Adjust the thin metal rod so that e.g. one of the aluminium absorbers is easy to place and remove.

Connect the cable from the GM tube to the socket on the backside of the counter.
Turn on the counter. It will automatically be ready for counting in 10-seconds periods.

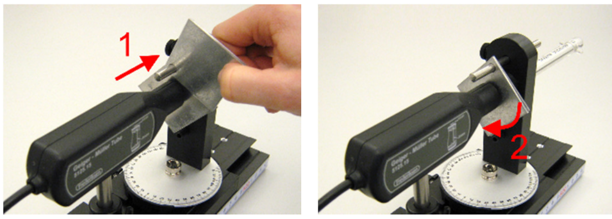
Each measurement is started by pressing *Start/Stop*.

Cut a square of paper the same size as the absorber plates. Cut a hole for the metal rod in one of the corners.



Adjust the distance to approx. 5 mm.

(Use e.g. 2 + 3 mm aluminium absorbers.)



Placing absorber plates on the rod

Procedure

The following applies to the whole experiment:

Write down counts for each measurement as well as the counting period (in seconds).

If something is placed between the source and the GM tube, write down *what* and *how much*,

1 – Background radiation

Start with all sources at least a metre and a half away. Count for at least 10 periods of 10 s.

Find the average. Now you know how much radiation is detected even without sources nearby.

2 – The beta source

Mount the beta source in the holder and count for 10 seconds without any absorber plates.

Place the paper square between source and GM tube and count for 10 s.

Replace the paper with 1 mm aluminium – i.e. two of the thin (0.5 mm) aluminium plates. Count for 10 s.

Replace the aluminium with a thin (1-1.2 mm) lead plate and count for 10 s again.

3 – The gamma source

Replace the beta source with the gamma source.

Repeat the four measurements above – but use a total of 4 mm aluminium resp. 4 lead plates with this source – when you see the results you will understand why.

4 – The Alpha source

Replace the gamma source with the alpha source.

You **must** adjusted the distance to 5 mm for this source.

Repeat the four measurements above (using only 1 mm aluminium and 1 lead plate this time).

Calculations

It is easiest to enter all data and calculations in a spreadsheet!

1 – Background radiation

Find as mentioned the average from series of 10 s measurements. Subtract this number in the following measurements:

If the background radiation average is 1.8 counts (per 10 s), round off to 2. If for instance the gamma source results in 549 counts (per 10 s), 2 of these are actually background radiation. The counts from the source itself is thus 549 - 2 = 547 counts per. 10 s.

This is called *correcting the counts for background radiation*.

The counts will vary slightly. You may therefore get a negative number when correcting very small counts – simply replace these with zero.

2, 3, 4 – The three sources

Make a table like this for *each* of the three sources:

Source:				
Period:	10	s		
Absorber:	(none)	paper	aluminium	lead
Counts:				
Corrected:				
% left:	100%			

Correct the counts for background radiation as mentioned before.

Calculate how much radiation you registered behind the different materials – as a percentage of the radiation *without* absorbers.
(Use the corrected counts.)

Procedure, continued

5 – The alpha source – more detailed

In this part of the experiment, you are about to measure with a little more precision.

As you probably noted in part 4, most of the radiation from the alpha source is stopped by the thin piece of paper while a small part still penetrates e.g. the thin aluminium plate.

We will examine this "residual radiation" closer by comparing it with the beta and gamma sources.

Perform these two measurements series for *each of the three sources*:

a – Count for 10 times 10 s with 1 mm aluminium between source and GM tube.

b – Add 3 mm of aluminium, making a total absorber thickness of 4 mm. Count again 1 times 10 s.

Calculations, continued

5 – The alpha source – more detailed

For each source, make a table like this:

Source:		
Period:	10 s	
Absorber:	1 mm Al	4 mm Al
Counts:		
A total of 10 measurements		
Average:		
Corrected:		
% left:	100%	

Find the average of the 10 measurements in each series and correct for background radiation. For the 1 mm series, we will consider this corrected average as the start value (100%) of the *residual* radiation.

Calculate (as a percentage) for each of the sources how much of the residual radiation that is left after passing the *extra* 3 mm of aluminium.

Discussion and evaluation

First a note on the stochastic nature of radiation: As you saw in part 1 and 5, repeated measurements don't give identical counts. The numbers will vary a little around an average. This is probably most pronounced in part 3. If it bothers you, you can change part 3 to use a longer counting period or average repeated counts (as in part 5).

When comparing radiation *types*, we must abstract from the different activities of the specific sources. It is thus important to look at *relative changes* – i.e. changes as *percentages*.

Based on the first measurements (1-4), please answer:

- Which material – aluminium or lead – is best as a radiation shield?
- Which of the radiation types beta and gamma radiation is easiest to shield against?

Now, assume that the alpha source in fact emits *two types of radiation* – of which the largest part is alpha radiation. Let us try to establish the radiation type of the rest:

Look at the results of part 5. Comparing the residual radiation (as percentage) from the alpha source with the two other sources – which one does it resemble most?

- Try to describe the composition of the radiation from the alpha source

Theory (background information)

The sources are constructed – as good as possible – to emit only one type of radiation. (But it is impossible to produce 100 % "pure" sources.)

The three types of radiation are:

Alpha: *Helium nuclei*, i.e. positive and relatively heavy particles.

Beta: *Electrons*, i.e. negative and very light particles.

Gamma: *Photons*, i.e. electrically neutral, massless quanta of light. The photons in gamma radiation has a *much* higher energy than visible light photons; apart from that they are very similar.

This experiment cannot detect properties like electrical charge! Other techniques are needed for that.

Two properties determine how penetrating the radiation is:

1 – The *type* of radiation – this is what you primarily study in this experiment.

2 – The *energy* of the individual particles or quanta. Although the relationship is not completely simple, more energy means more penetration – in broad terms.

Teacher's notes

Concepts used

Alpha, beta, gamma radiation.
Background radiation.

Mathematical skills

Percentages

About the equipment

The GM counter specified is compatible with any GM tube from Frederiksen: Large, small, BNC or Jack plug. (512515 is the least expensive.)

Other counters may be used – the students should in that case receive instructions for use.

The GM tube is sensitive to all three types of radiation. The mica window will, however, will slow alpha particles down and therefore reduce their measured range. The radiation will be detected when the GM tube is sufficiently close to the source.

In general, Geiger tubes have a very low efficiency for gamma detection (which is why the Risø gamma source is 10 times stronger than the other two).

Note: Check in advance that you get a very high count rate from the alpha source at the distance given in this manual. If the GM tube window is too thick, the distance must be reduced (instruct the students).

The alpha source is Am-241. The energy of the alpha radiation is approx. 5.5 MeV. The alpha decay is often accompanied by gamma radiation. This gamma radiation has markedly lower energy than the radiation from a Cs-137 gamma source; although still penetrating, the low energy gamma radiation is absorbed easier.

The beta source is Sr-90 in equilibrium with Y-90. The two decays emit beta particles with a maximum energy of 546 keV, resp. 2280 keV.
The beta source only emits gamma radiation in 0.02 % of the decays. Together with the low gamma efficiency of the GM tube, the beta source will appear as almost 100 % pure.

The gamma source is Cs-137 which in 94 % of the cases will beta decay to Ba-137* that decays to the ground state by emission of a 662 keV gamma quantum. The source is built to absorb most of the beta radiation before it exits the source.

Didactic considerations

By starting with the beta source, the students will experience the "purest" results first.

After that, gamma radiation is seen to be more penetrating,

Lastly, the alpha source and its associated gamma radiation is investigated.

Types and availability of sources

Frederiksen Scientific cannot provide sources unless we receive documentation that the customer and the end user are entitled to handling and using such sources.

Frederiksen Scientific only provides sources of the "Risø" type – seen on the photo on p. 1 – but we make equipment that is compatible with two other widely used types:

Disc-shaped (Ø 25 mm) sources
Cylindrical (Ø 12 mm) sources

The nuclei used are detailed in the "About the equipment" section.

It must be noted that the Am-241 and Sr/Y-90 sources must be specifically constructed for alpha, resp. beta emission. (At least Am-241 sources also come in a "gamma rays only" version.)

Detailed equipment list

Specifically for Risø sources

510000	Risø sources, complete set
514100	Experiment bench, including absorbers

Specifically for disc sources

	Three disc sources as described above
514120	Experiment bench, disc source including absorbers

Specifically for cylinder sources

	Three cylinder sources as described above
514110	Experiment bench, cylinder source, including absorbers

Common setup

512515	GM tube with BNC plug
513610	GM counter (or similar)

Consumables

Paper (normal copier paper, 80 g/m^2)