Alpha particles, the spark detector

Experiment number	138430-EN	*Topic*	Radioactivity		
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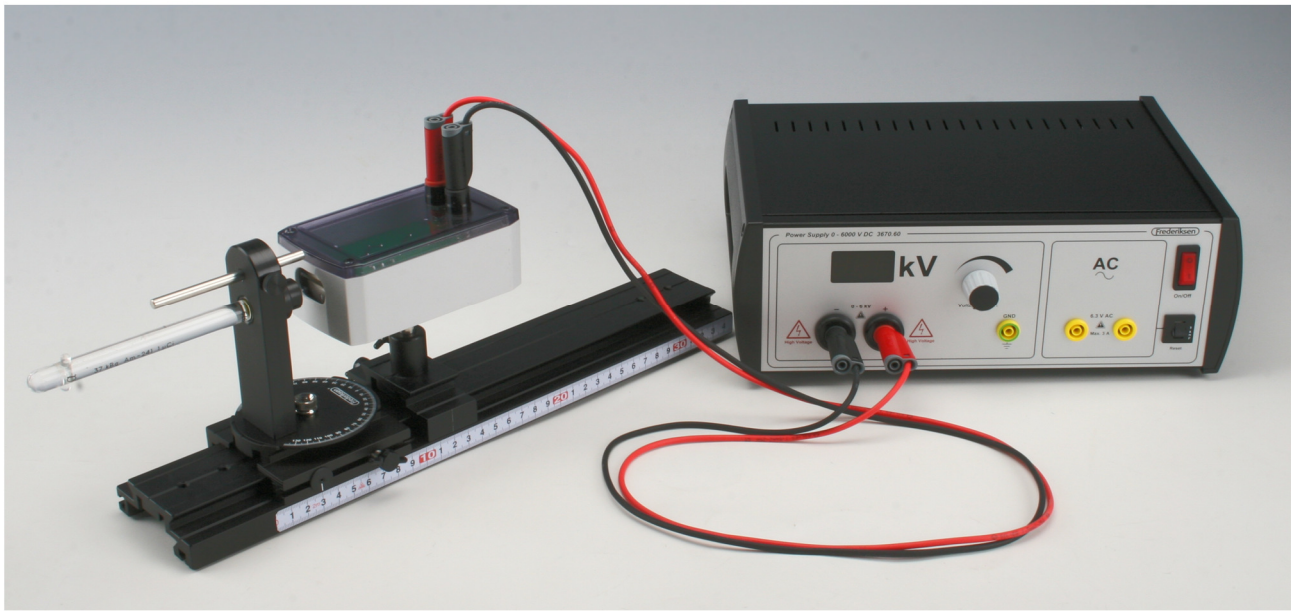

Objective
In this experiment we study the alpha radiation from a radioactive source. We will investigate what it takes to stop the radiation and we will find the range of alpha particles in air.

Principle
The spark detector has two electrodes carrying a high voltage – just below the threshold for spontaneous sparking. When an alpha particle pass through the air between the electrodes, some of the air molecules are ionized. The ions and the free electrons will trigger a spark.

Different materials can be placed between the source and the detector and the distance can be varied.

Equipment
(See *Detailed equipment list* on p. 4)

Alpha source
Spark detector
High voltage supply
Experiment bench
Food wrap / cling film
Other absorbers like:
- Lead
- Aluminium foil
- Paper

Work carefully
The experiment involves a radioactive source and all relevant precautions must be followed.

Keep a suitable distance to the source
Limit the time you need to handle or stay close to the source

High voltage is used in this experiment.
The high voltage supply is provided with a current limiter to prevent dangerous current levels. But follow these rules anyway:

Turn off the power supply while you make changes to the electrical circuit
Turn on the power, only when both wires are plugged in at both ends

The experiment can be performed safely when you follow all instructions from your teacher.

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Procedure

Set up as shown on the photo on p. 1 – but with 15 to 20 cm distance between source and detector.

With the detector connected to the high voltage supply, turn the voltage up slowly. At some voltage, spontaneous sparking will occur between the electrodes – when it happens, turn slightly down until sparking ceases completely. (3 – 6 kV is needed.)

The detector is now ready for use.

1 – What is needed to block the radiation?

Reduce the distance between source and detector to 0.5 – 1.0 cm.
The detector should be loudly sparking. (If not, go back to the larger distance and re-adjust the voltage.)

Try to place a thin lead absorber between source and detector. Write down what happens.

Remove the lead again and check that the detector sparks normally.

Repeat with the following materials and write down the results each time:

- thin (0.5 mm) aluminium absorber
- aluminium foil
- ordinary paper
- cling film (polypropylene)

Note: **Don't** place a finger in front of the source. If you want to investigate a material resembling living tissue: use a slice of salami (and throw it out afterwards).

2 – The range of alpha particles in air

Before we proceed, we need to have control over the zero point of the scale on the bench.

For the Risø source screwed tight into the source holder, the radioactive material is placed 3.5 mm behind the front of the holder[1].

Measure (without high voltage!) the distance between electrodes and housing of the detector.
In the example below, 7.5 mm is used.

The total "internal" distances (using these figures) is 3.5 mm + 7.5 mm = 11.0 mm = 1.10 cm.
This is called d_0 on the photo to the right.

Place the saddle carrying the detector at the position 10 cm + 1.10 cm = 11.10 cm.

Place the source holder so the edges of the detector, resp. the source holder has zero distance. (The holder should not be pushed into the opening in the detector.)

Keep the *source holder* in this position; tighten the finger screw. (Move only the detector from now on.)

Now the distance between source and spark gap is as indicated on the scale – minus 10 cm.

Increase the distance between source and detector, just until the alpha radiation is no longer detected. Find this place as precisely as possible by shifting the detector both ways in small steps.

Now you have the range of alpha radiation in air R_{air}.

3 – The range of alpha particles in plastic

Cling film can be made of e.g. polypropylene (PP) with a thickness of 8 µm (0.008 mm). This is much thinner than paper.

Place one layer of cling film between source and detector. Make sure there is only one layer but don't stretch the film.

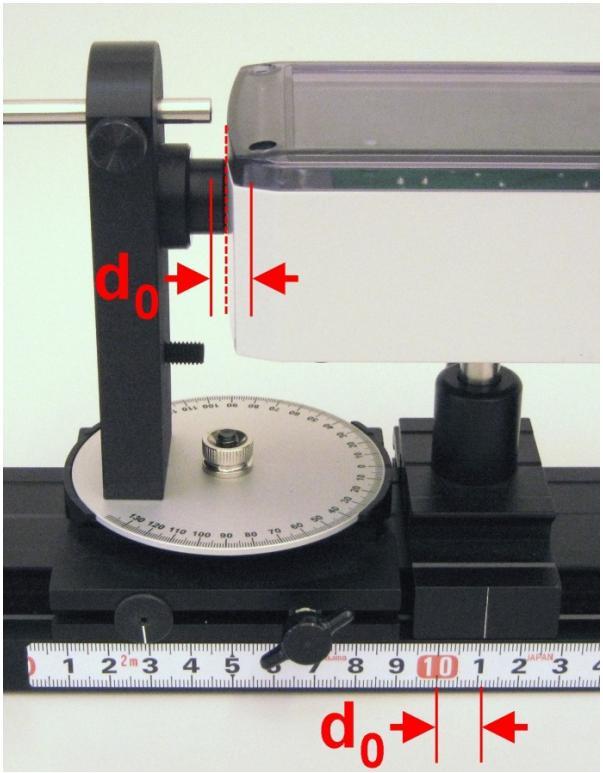
Measure as before the range of alpha particles through *1 layer of film and air*.
Call it R_1.

Repeat with two layers of film. Call the result R_2.

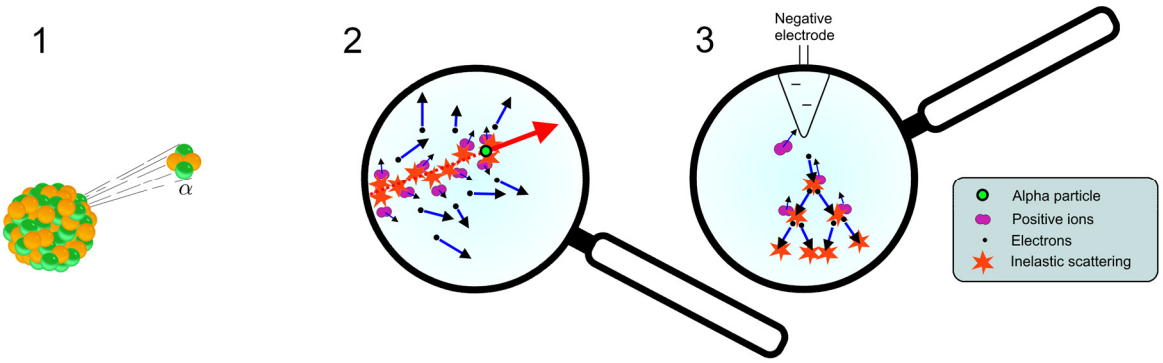
Continue until there is no sparking – no matter how close the source is to the detector.

How thick a layer of air does it take to slow down alpha radiation as much as one layer of cling film? (In average.)

Try to invent a method to *measure* the thickness of one layer of film (otherwise you will have to trust the manufacturer's information – or use 0.008 mm).



[1] For other types of sources, ask your teacher for information



Background knowledge

Figure 1: Alpha particles are emitted when a Am-241 nucleus decays. An alpha particle is the same as a He-4 nucleus.

Figure 2: When the alpha particle pass through air it leaves behind a trail of ions and free electrons.

Figure 3: The free electrons in the air are accelerated to high speeds in the strong electric field near the sharp electrodes. When they collide with new air molecules, these can also be ionized. This generates a cascade of charged particles that can carry an electric current – a spark is triggered.

Calculations

In part 3 you will need the result from part 2, the range of alpha particles in air, R_{air} .

When 1 layer of film reduces the range to R_1 , The slowing down in the film must be equivalent to that in an air layer of thickness R_{air} - R_1 .

Similarly, find the air layer thickness corresponding to 2 film layers, 3 film layers, etc.
Divide by 2, (3 etc.) to get an average value per film layer.

Calculate an overall average for these values.

How many times faster are alpha particles slowed down in plastic – compared with air?

Finally another calculation: How thick a layer of plastic is just enough for stopping the alpha radiation completely? This result we will call $R_{Plastic}$.

If you found a way of measuring the thickness of one layer of cling film: Write down an explanation of the method.

Discussion and evaluation

If alpha particles are penetrating living tissue the ionisation can create harmful chemical compounds or radicals – or even directly damage the chromosomes in the cells.

The dead (cornified) outermost layer of the skin is between 10 and 40 µm thick. There is no similar layer of dead cells in the gastrointestinal tract.

Under which circumstances is alpha radiation dangerous for humans?

Try to find table values to compare your own range values with – especially the range of alpha particles in air.

Teacher's notes

Concepts used

Radioactivity
Alpha particles
Ionisation

Mathematical skills

Average
"Rule of three" (fractions)

About the equipment

Try to obtain PP film with a thickness of 8 µ – or even thinner. Unfortunately this will not always be on the label. Thickness is more important than the type of plastic.

Follow the precautions below in case the detector must be opened (read more in the product manual):

Remove the wires from the sockets on the detector. Short the two sockets with a wire.

The enclosure can be opened now.

Connect to high voltage **only** when the housing is closed. **Never** try to connect directly to the circuit board through crocodile clips or similar – **it is mortally dangerous.**

The electrodes are razor sharp – don't cut your fingers.

Types and availability of sources

You will need an Am-241 alpha source.

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

It must be noted that the Am-241 source must be specifically constructed for alpha emission.
(Am-241 sources also come in a "gamma rays only" version.)

Detailed equipment list

Specifically for Risø sources

510010	Risø alpha source. (Included in 510000 Risø sources, complete set)
514100	Experiment bench, including absorbers

Specifically for disc sources

	Alpha disc source as described above
514120	Experiment bench, disc source including absorbers

Specifically for cylinder sources

	Alpha cylinder source as described above
514110	Experiment bench, cylinder source, including absorbers

Common setup

512110	Spark detector
367060	High voltage supply (0-6 kV)
105740	Safety cable 100 cm, black
105741	Safety cable 100 cm, red

Consumables

118530	Aluminium foil, 20 m roll
118540	Cling film, 60 m roll

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