Laboratory Exercise A
(Wednesday 14-19)

Interaction between Radiation and Matter

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Overview Laboratory Exercise A

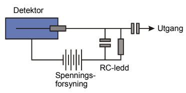
- Title: **Introduction to radioactivity**
- Learning goals:
  - To understand the relationship between amount of radioactive material and desintegrasjon rate.
  - To understand the relationship between count rate and desintegrasjon rate.
  - To understand the uncertainty in measured number of counts and be able to calculate the uncertainty in numbers derived from such numbers.
  - Be able to use a radioactivity detector.
  - To know and understand the basic principles for work with open radioactive sources.
  - Be able to conduct contamination checks.

Basic Principle of Detection

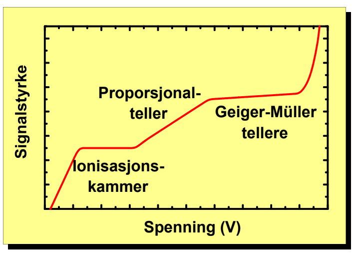
- Almost all radioactivity detectors are based on detection of the ionisations and/or excitations cased either directly or indirectly.
- This principle can easily be illustrated with an electroscope:
  - Two metal foils are charged with the same polarity -they will repel each other.
  - Ionisation in the gas will de-charge the metal foils.

Gas Filled Detectors

- An electric potential difference is created between the detector chamber and the centre electrode
- Radiation hitting the gas in the detector will ionise the gas. I.e. ions and electrons are created along the path of the radiation track.
- If the potential difference is big enough, negative ions and electrons will be separated from positive ions. Thus, a current will flow through the circuit consisting of the detector and the external electronics.

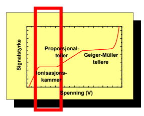


Types of Gas-Filled Detectors



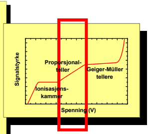
Ionisation Chamber

- The current created by the radiation is very small and huge amplification is necessary.
- Ionisation chambers can not count single events (e.g. one β particle). The current is much to weak for this to be possible.
- As α particles generates substantially more ion pair than a β particle, ionisation chambers is best suited for α-detection.



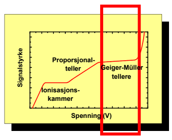
Proportional Counters

- At a certain voltage the ions will start to ionise other gas molecules. I.e. secondary ionisations will occur.
  - These secondary ions will also be accelerated and might again ionise still other molecules.
  - In this way amplifications of the order of 10^6 can be achieved.
- The signal is strong enough to enable the operation of such detectors as counters. I.e. each separate incident in the detector is counted.
- The output signal is proportional to the amount of energy in each radiation event.



Geiger-Müller Detectors

- If the voltage is increased even more, not only secondary ionisations will occur but also excitations of the gas which causes UV emissions.
- These UV rays will start ionisations at places in the detector chamber which so far have not been ionised.
  - This will give raise to new cascades of ionisations.
  - Thus, the detector will produce very strong output signals.

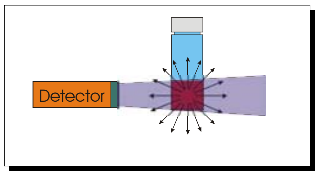


Geiger-Müller Detectors, cont.

- However, the generation of new cascades will continue for ever after the first event.
- This was originally solved by turning the detector off for a short while after each event.
- Today, the GM detectors have additions of special gases which acts as quenchers, i.e. they terminate the generation of the secondary events after a short while.
- A GM-detector is very sensitive, but do not have the ability to distinguish between events with different energies.

Radioactivity Counting

- The ratio between the amount of radioactivity emitted from the source and counted by the detector is given by the *detector efficiency, ϵ.*



Counting uncertainty

- The Poisson distribution describes random events.
- The likelyhood of getting a given value x is given by

$$P(x) = \frac{\bar{x}^{x} e^{-\bar{x}}}{x!}$$

provided the population (number of nuclei) is large.

- For the Poisson distribution, the standard deviation is given by

$$\sigma = \sqrt{\bar{x}}$$

Propagation of Errors

- Assume you have measured x and c is a contant, then

$$x \pm \sigma \Rightarrow \begin{cases} x_c = x \times c \\ \sigma_c = \sigma \times c \end{cases}$$

- Assume you have measured x and y, then

$$\begin{cases} x \pm \sigma_x \\ y \pm \sigma_y \end{cases} \Rightarrow \begin{cases} z = x \pm y \\ \sigma_z = \sqrt{\sigma_x^2 + \sigma_y^2} \end{cases}$$

Two important examples

- You have measured the background equal to 1293 counts for 600 s.

? What is the background, with uncertainty, in cpm?

- You then measured a sample for 300 s. The number of counts was 3651.

? What is the count rate, with uncertainty, in cpm?
? What is the net count-rate?