Radioactivity

- **9. Radioactivity**
  - Use efficient methods to collect as much radioactive material as you can in a room. Measure the half-life of the material you have collected.

Corinna Burghardt

Comparison of different methods

1. An air sampler is used to pull air through filter paper for several hours.
2. A pump is used to pull air through olive-oil.
3. An air-balloon is rubbed with a wool cloth.

- Only doubling of background radiation rate .
- self-absorption of oil is very important
- no clear result

Comparison of different methods

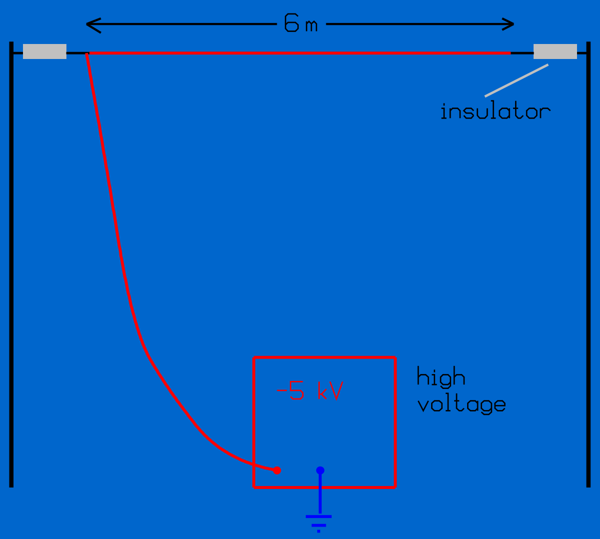
4. A polystrol plate rubbed with wood.
5. The radioactive material is allowed to diffuse into a canister where it adsorbs onto activated charcoal.

- Only doubling of background radiation rate .
- We could not measure and compare this with standards.

6. A silver wire of about 6m length was put to - 5kV for several hours

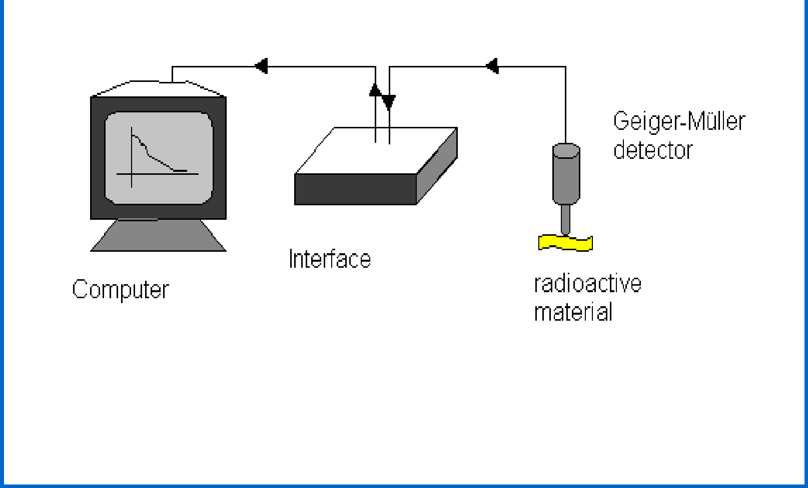
- This was the most efficient method,
- we got a maximum about 400 times the rate of background radiation.

Experimental setup collecting radioactive samples



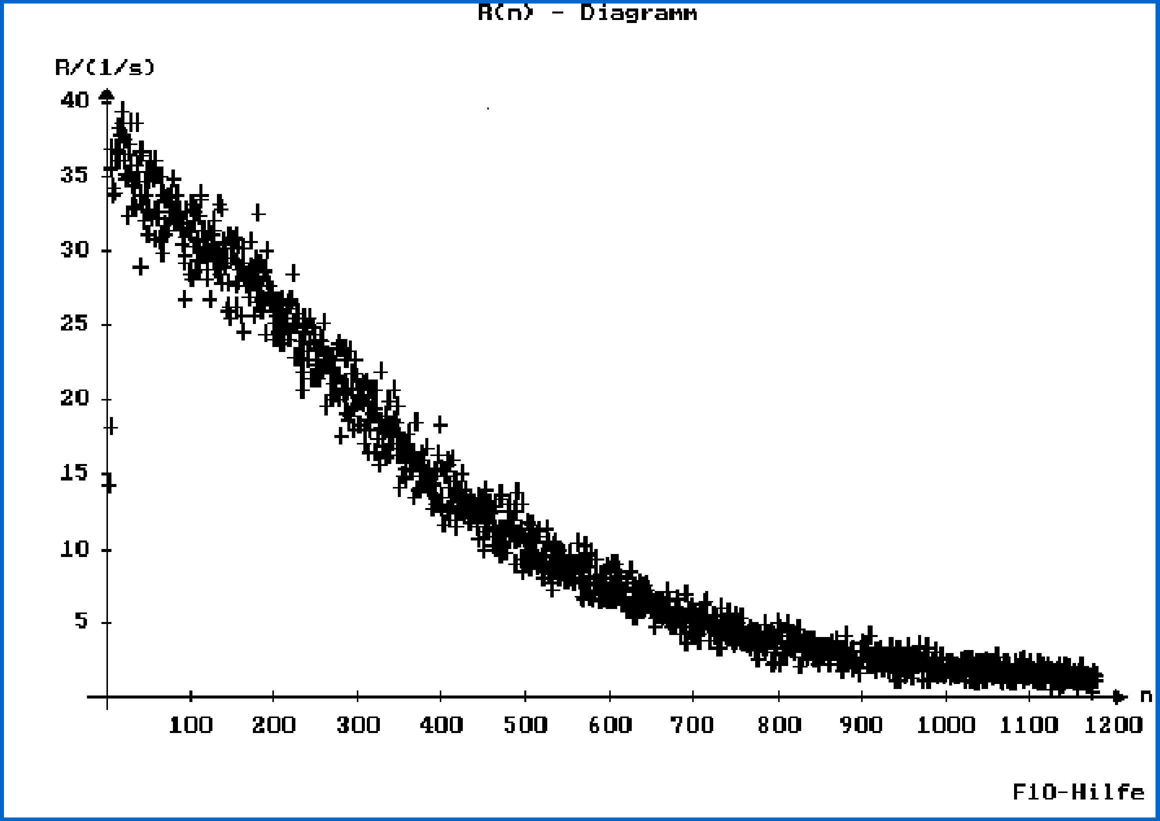
- Silver wire 6m length at -5 kV in the cellar or in the 1. stage
- Collecting time:
  2 hours-24 hours

Measuring the rate of decay I



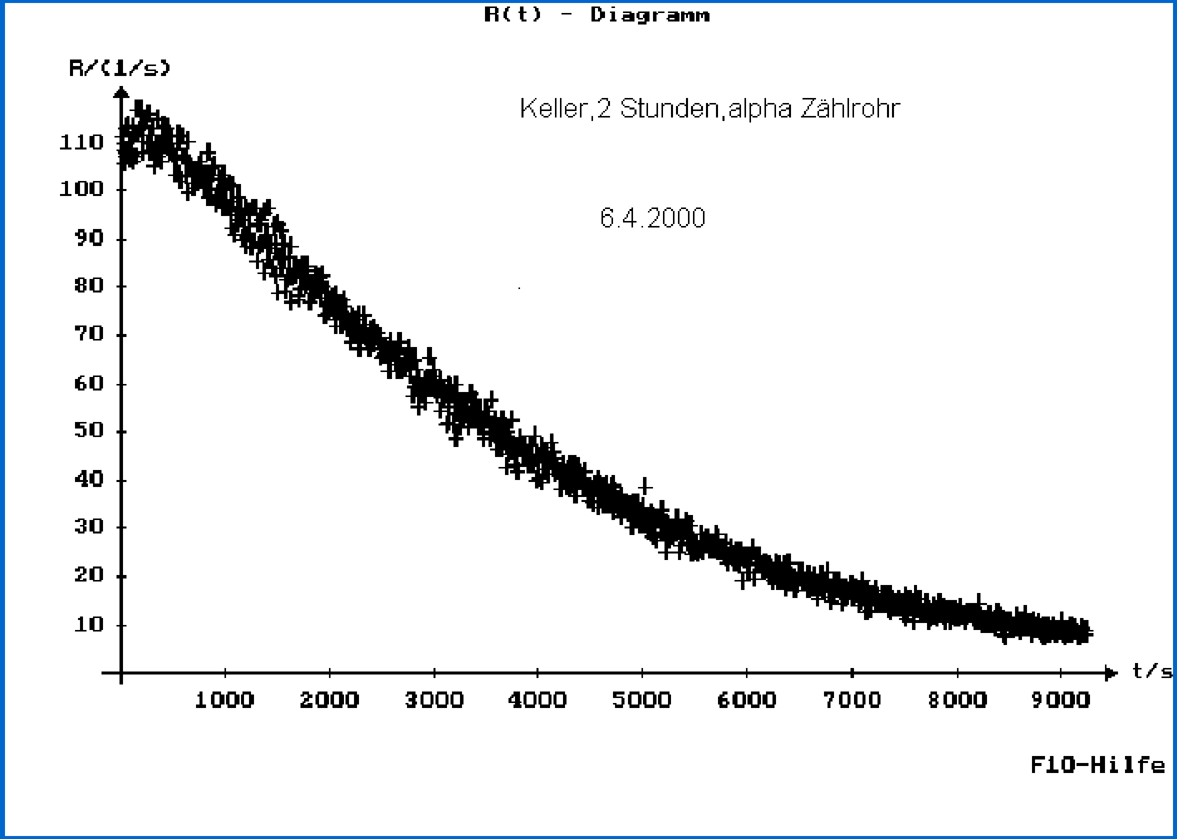
- Geiger-Mueller detector interfaced with a computer
- Measuring for 10 s, calculating the rate
- 2500 times, that equals a time of about 8 hours

Typical measurement of decay rate



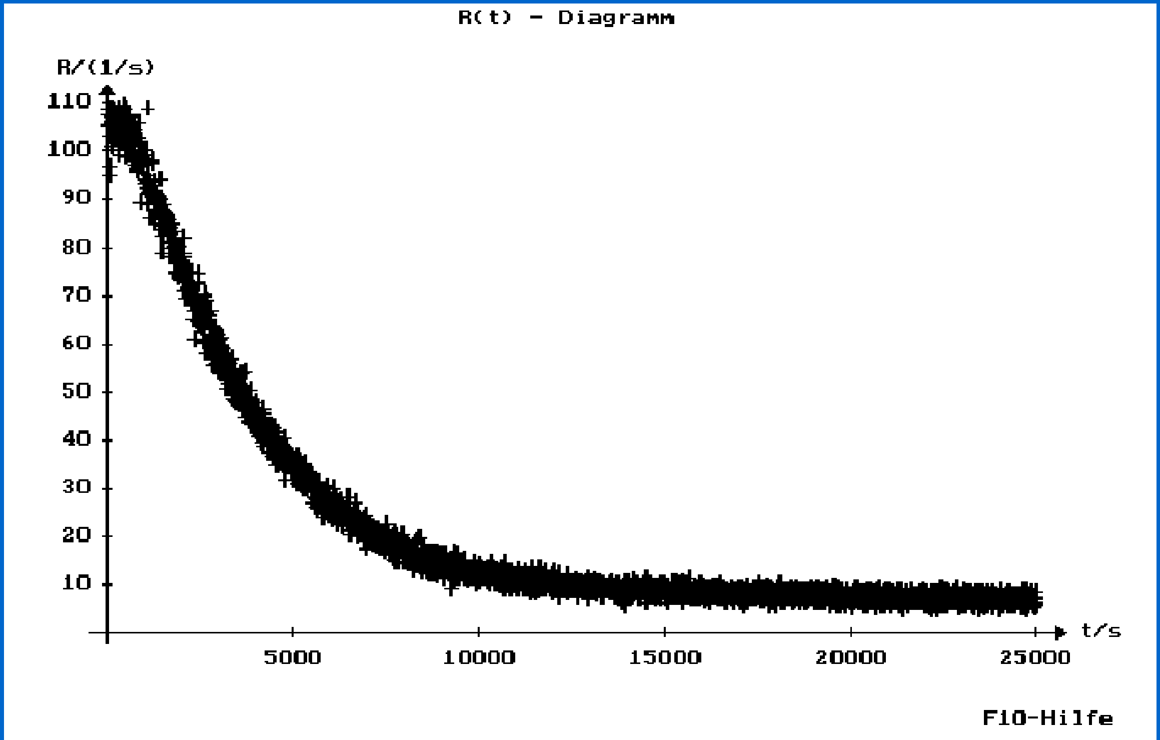
- Collecting time for the sample 2 hours in the first stage, physics room

Typical measurement of decay rate



- Collecting time for the sample 2 hours in the cellar

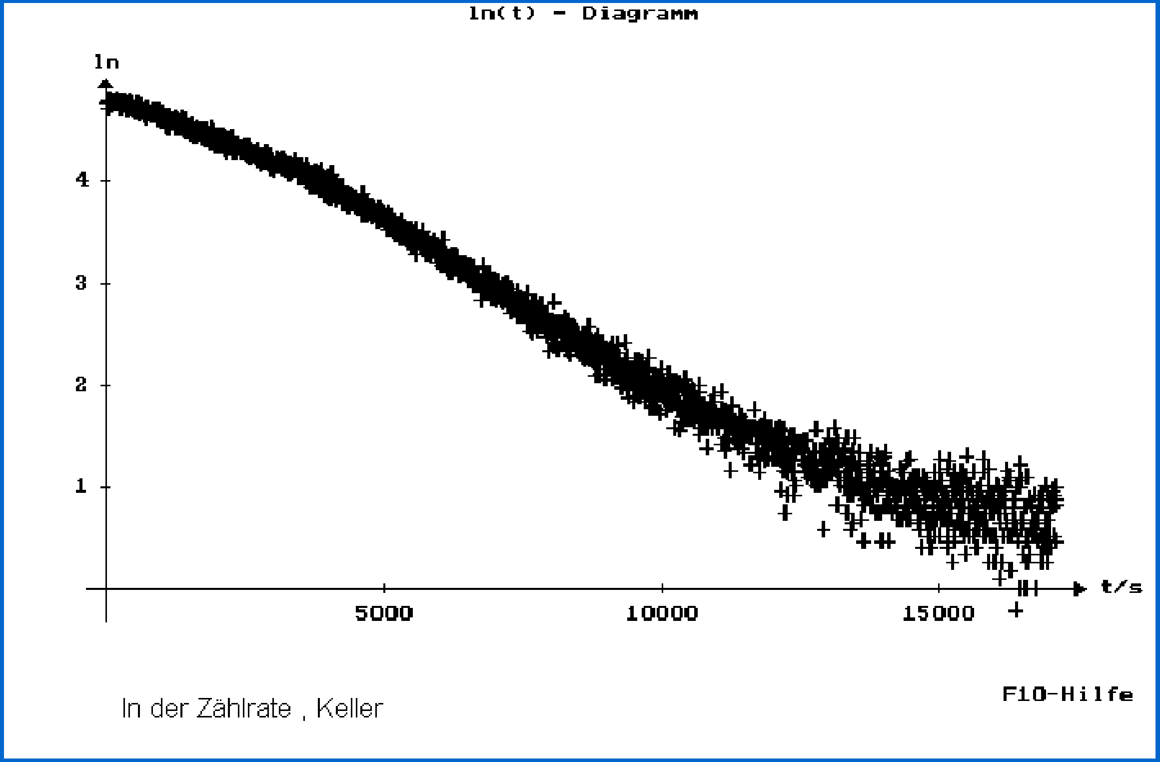
Typical measurement of decay rate



Zerfallsrate in Abhängigkeit von der Zeit

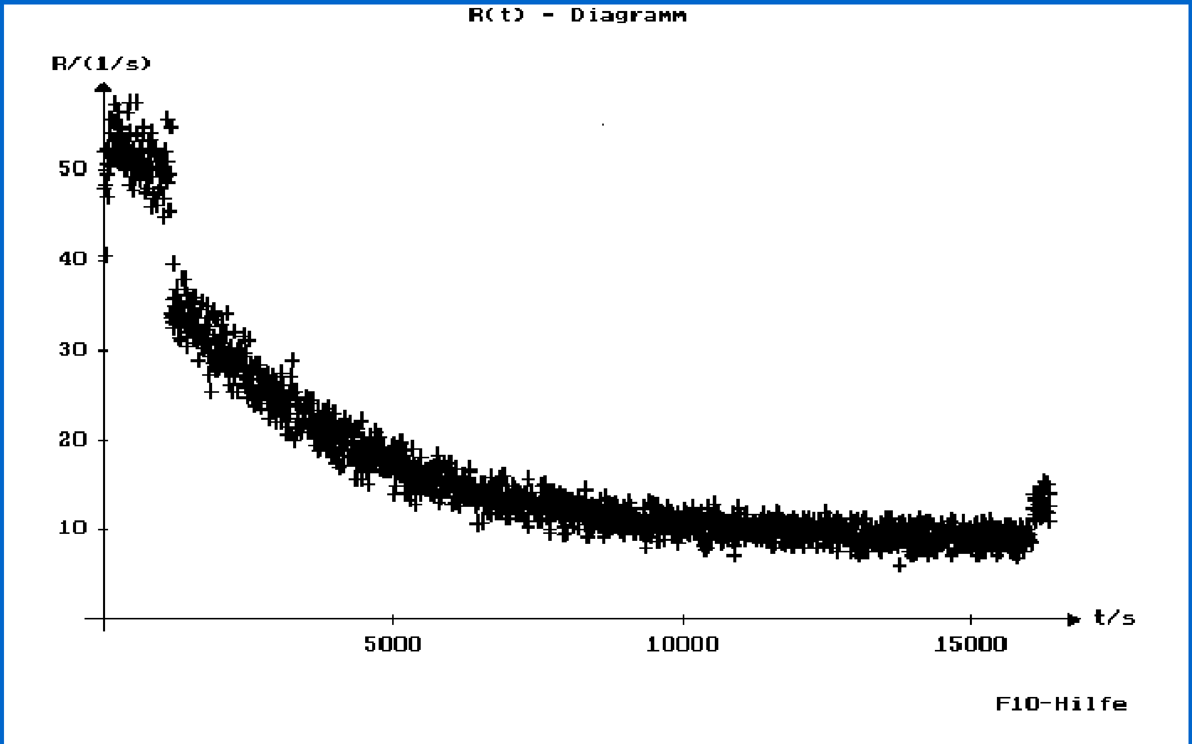
- Collecting time for the sample
  20 hours in the cellar

Exponential decay



- Collecting time for the sample 2 hours
- ln of rate, indicating that we got a mixture of radioactive materials

Distinguishing alpha´s and beta´s



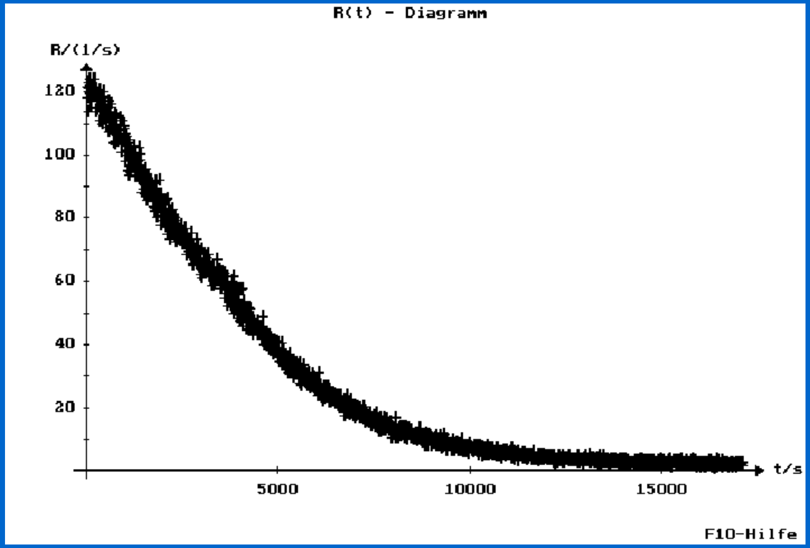
- a sheet of paper was placed and removed after some time between sample and counter

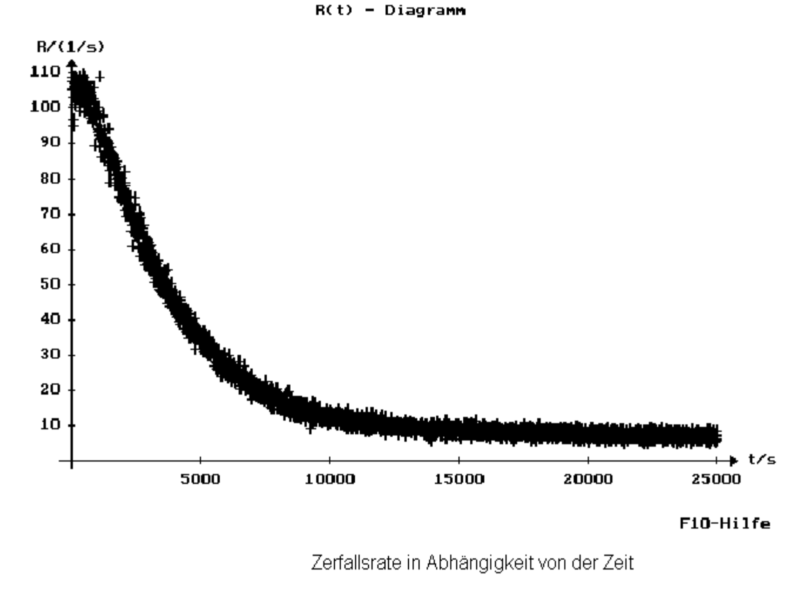
Comparison of different collecting times

for 22 hours a greater part of long-life material

2 hours

22 hours





Half-life of the mixture

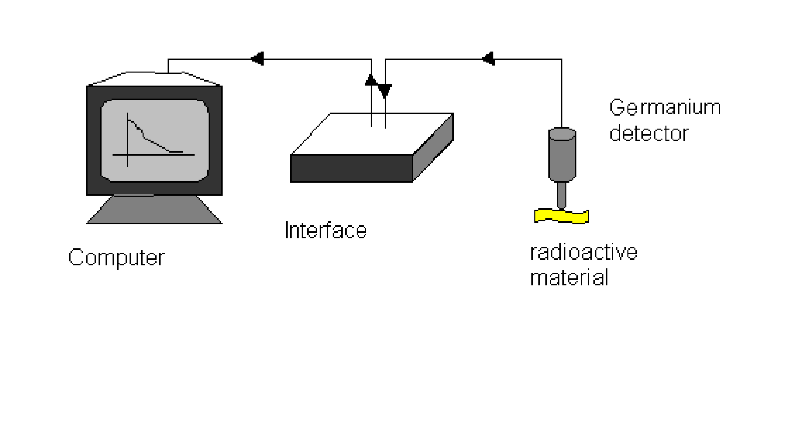
As it can be seen from the graphs showing the radioactivity of the whole mixture, its half-life is approximately

1 hour.

Gamma-ray spectroscopy

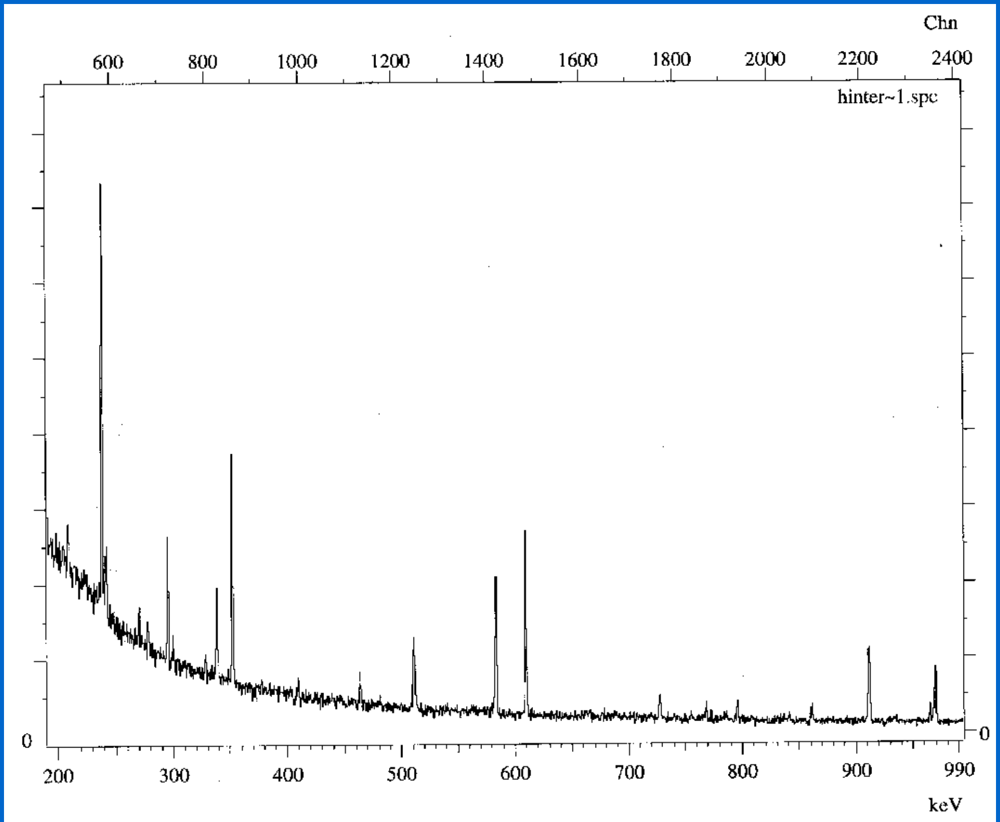
- The same experiment is done with the only difference of analysing the radioactive material with a germanium detector.
- A germanium detector works on the basis of putting the incoming gamma rays into different channels of energy, with each energy being characteristic of one element.

Measuring the rate of decay II



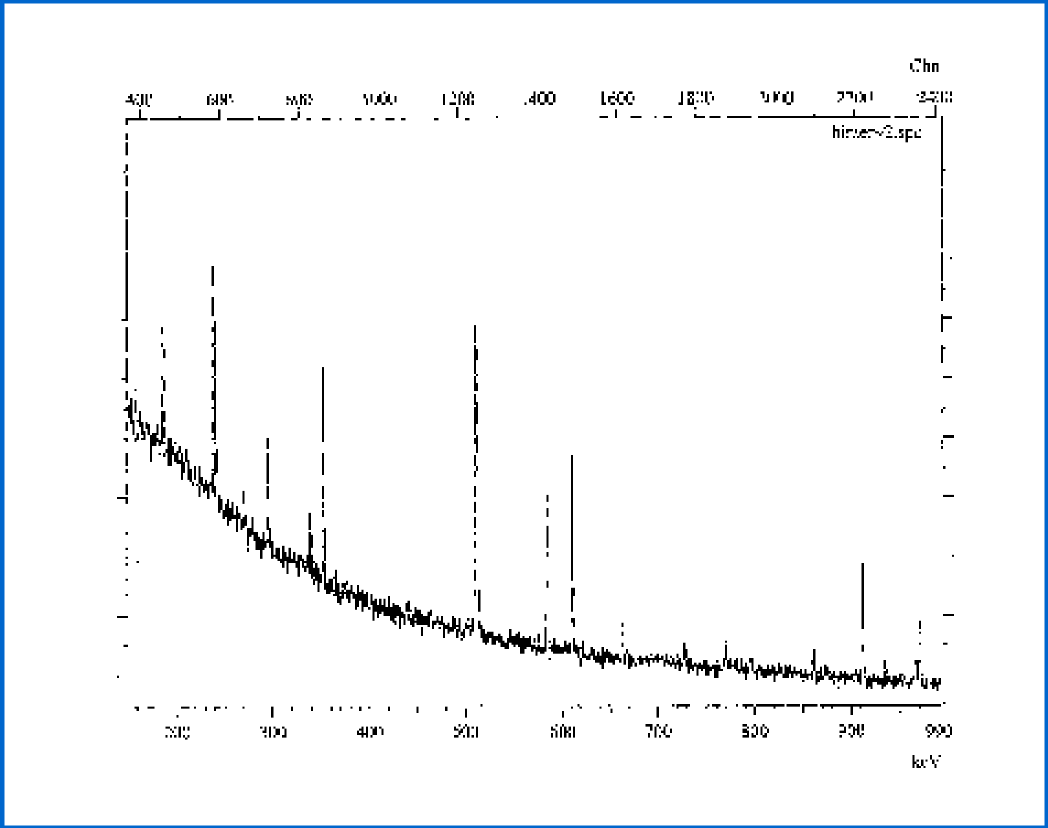
- germanium detector, interfaced with a computer
- measurement stopped after a certain time and restarted to observe the half-lives

Typical measurement results



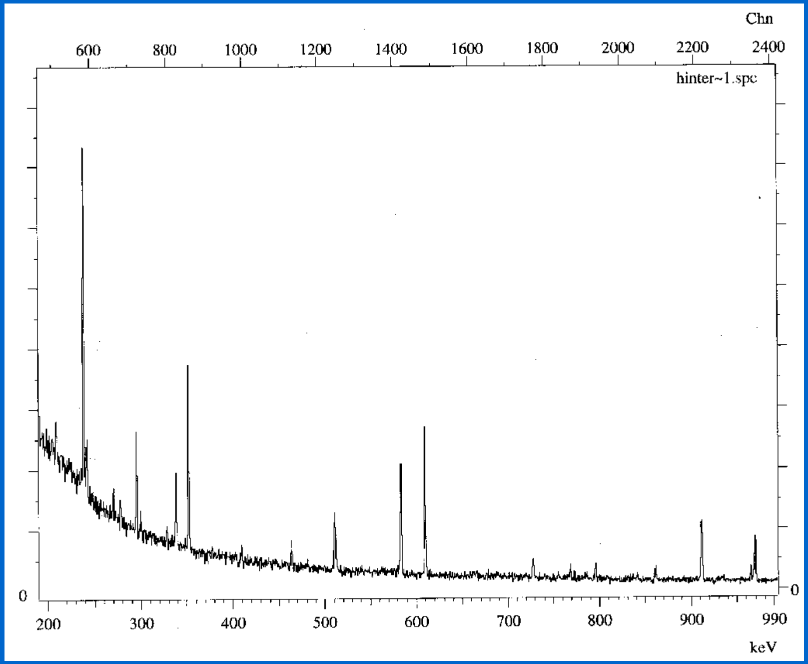
the general background radiation

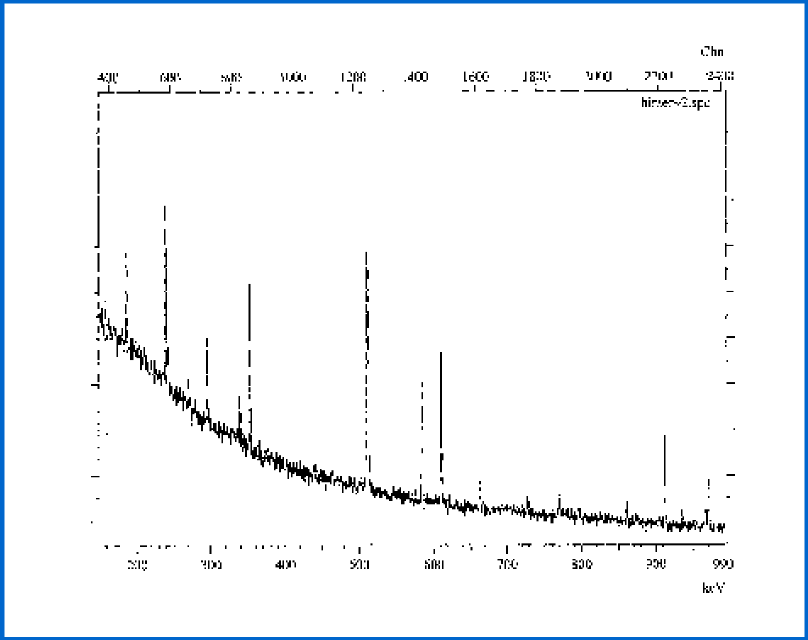
Typical measurement results



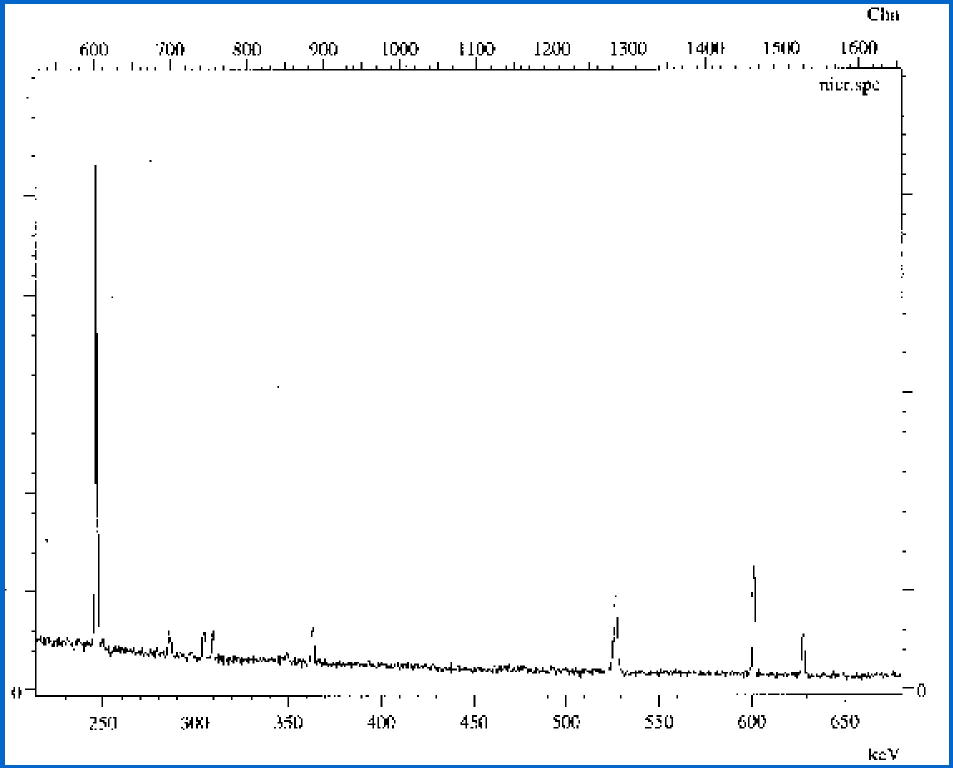
the observed spectrum with the radioactive material on the detector

Comparison of background and general radioactivity





Typical measurement results

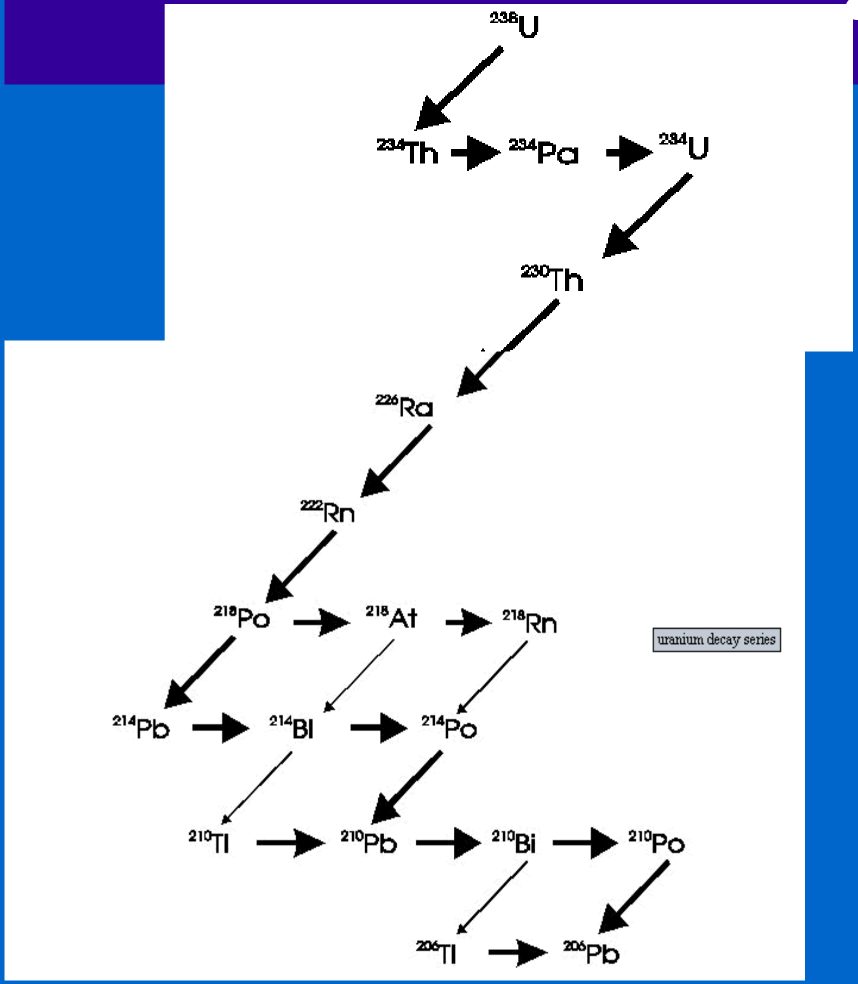


selected spectrum of the material wiped off the NiCr wire

Elements present in the radioactive spectrum

Energy of the Peak [keV]	Element
239	Pb 212
242	Pb 214
295/300	Pb 214/212
352	Pb 214
585	Tl 208
609	Bi 214

- The radioactive decay chain of Uranium 238, through radon , to a stable form of lead



The radioactive decay chain of Thorium 232

Th 232 =>

Ra 228 =>

Ac 228 =>

Th 228 =>

Ra 224 =>

Rn 220 =>

Po 216 =>

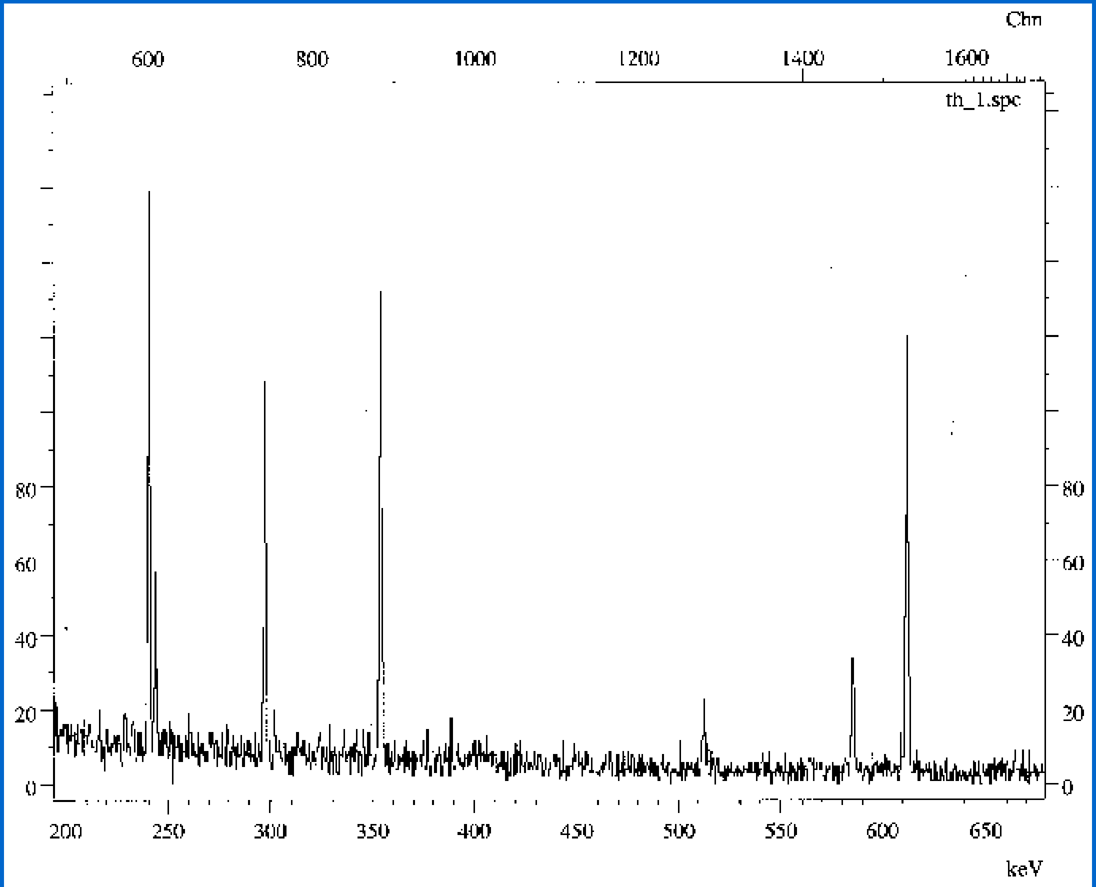
Pb 212 =>

Bi 212 =>

Po 212 / Tl 208 =>

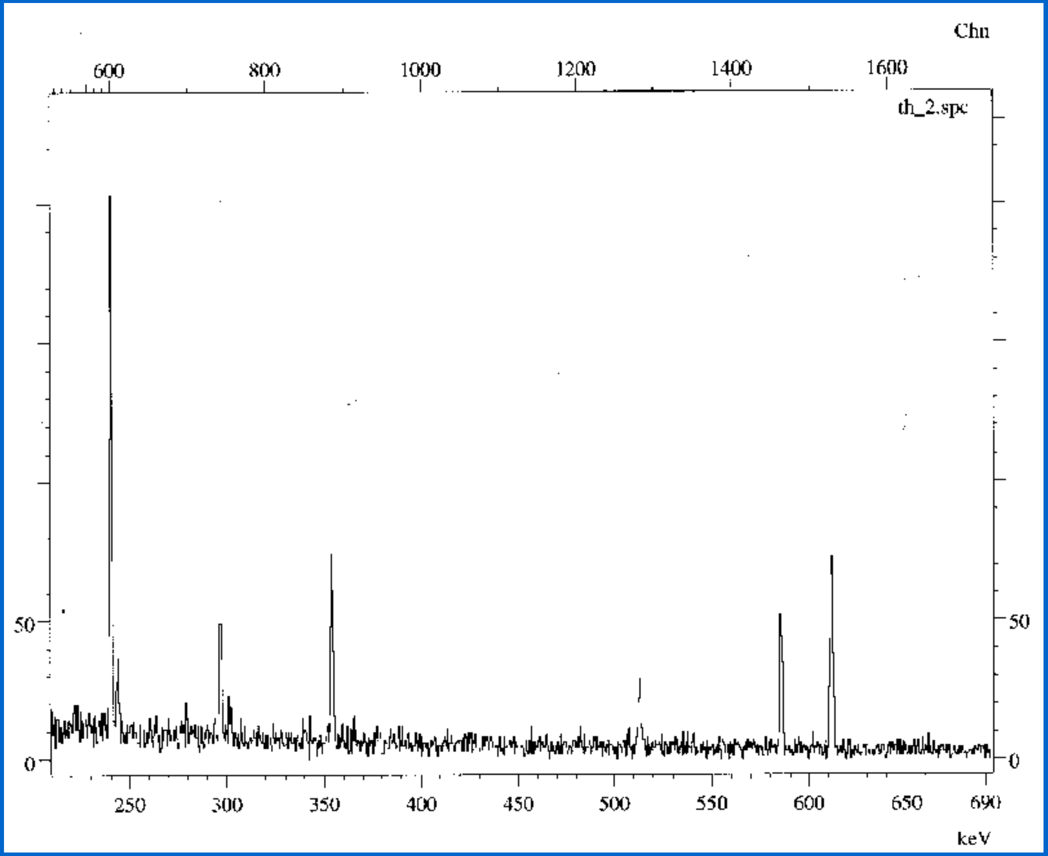
Pb 208

Typical measurement results



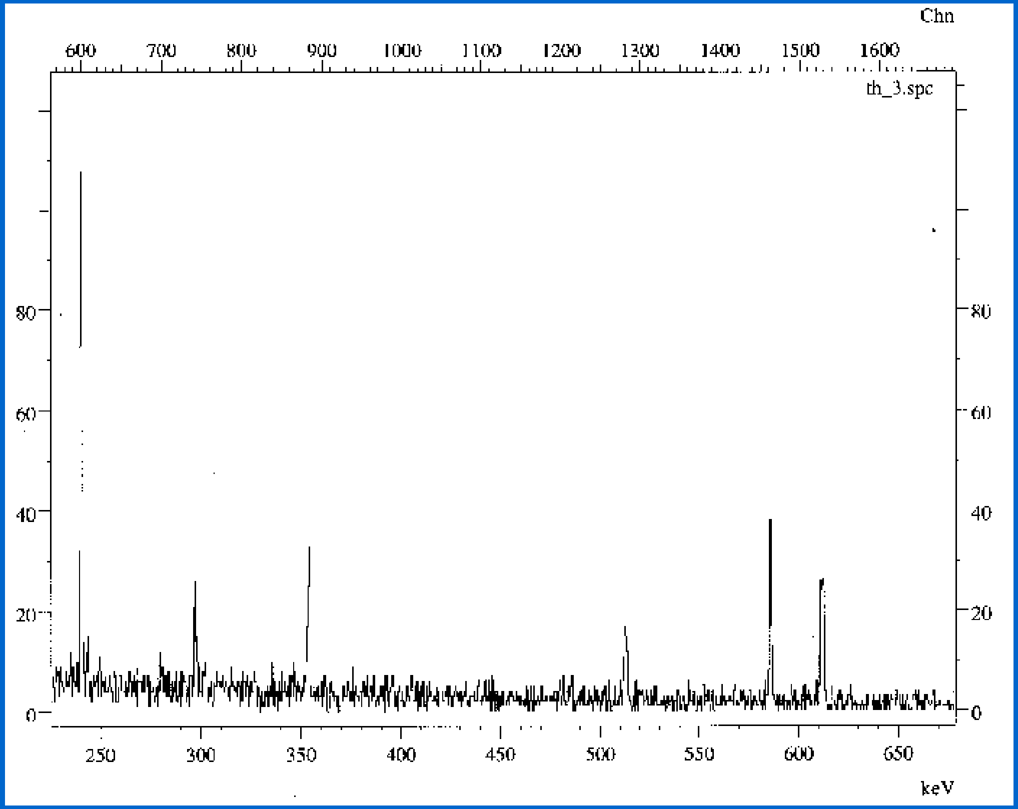
radioactive spectrum after 30 min

Typical measurement results



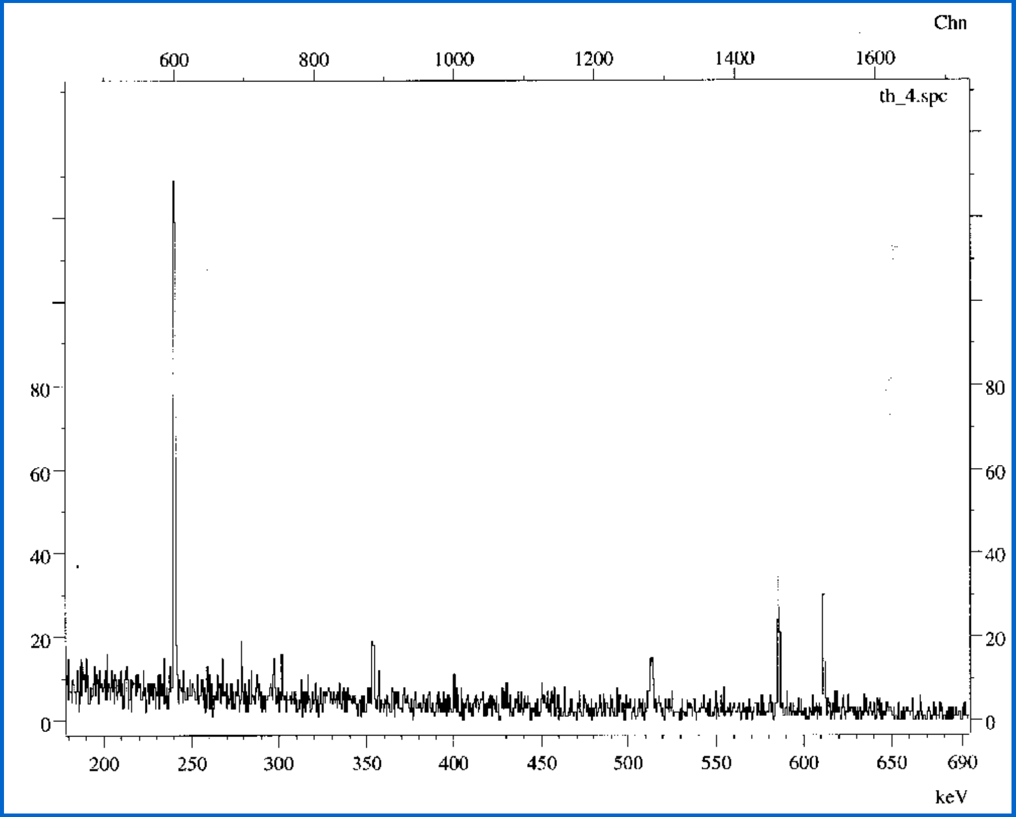
radioactive spectrum after 75 min

Typical measurement results



radioactive spectrum after 95 min

Typical measurement results

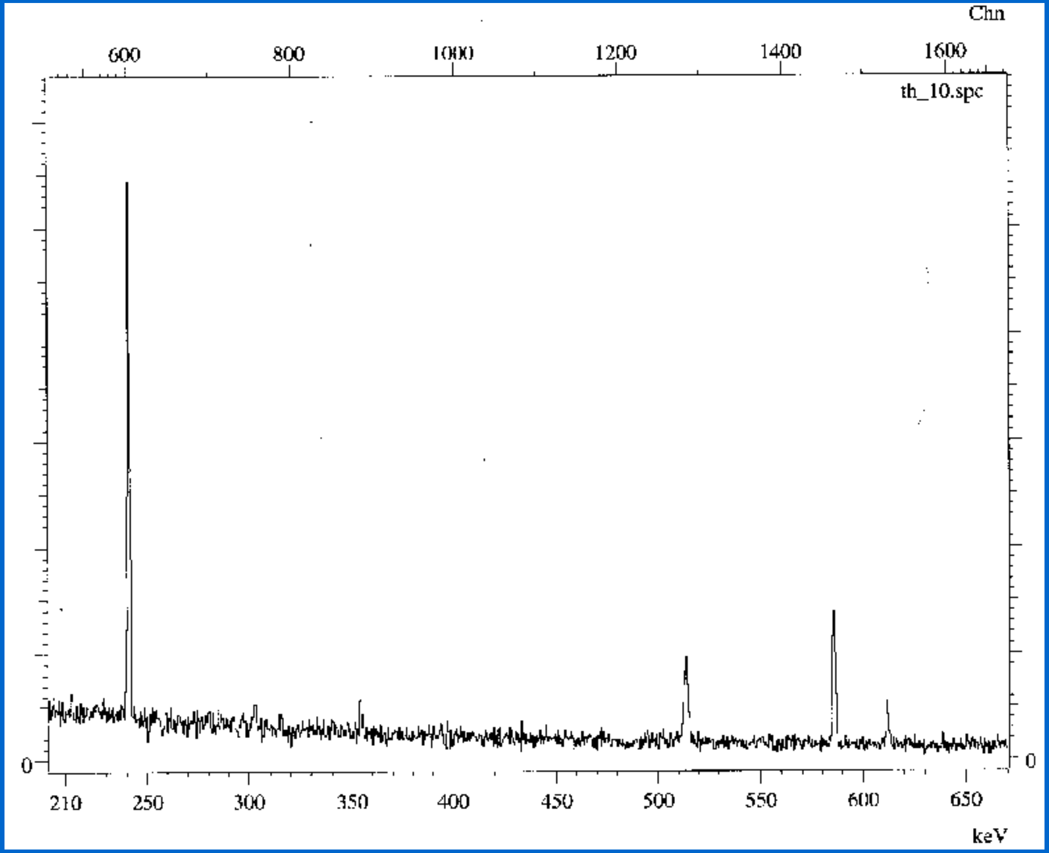


radioactive

spectrum

after 2 hours

Typical measurement results



radioactive spectrum after 10 hours

Half-lives calculated from experimental results

Pb 212	10,06 h	(10,64 h)
Pb 214	28,8 min	(26,8 min)
Tl 208	not observable	(3,05 min)
Bi 214	25 min	(19,9 min)

Half-life from literature (Uranium chain I)

- Rn 222 → Po 218 + α
  - Rn half-life 3,82 days n1
- Po 218 → Pb 214 + α .
  - Po half-life 183 s (3,05 min) n2
- Pb 214 → Bi 214 + β
  - Pb half-life 1608 s (26,8 min) n3

Half-life from literature (Uranium chain II)

- Bi 214 → Po 214 + β
  - Bi half-life 1182 s (19,7 min) n4
- Po 214 → Pb 210 + α
  - Po half-life 164 μs n5
- Pb 210 → Bi 210 + β
  - Pb half-life 22 years

Half-life from literature (Thorium chain)

- Po 216 → Pb 212 + α
  - Pb half-life 10,2 min n1
- Pb 212 → Bi 212 + β
  - Bi half-life 25 min n2
- Bi 212 → Tl 208 + α
  - Tl half-life 3 min

Theoretical model and experimental results

- Theoretical model for collecting radioactivity on the wire.
- Prediction of time dependency for the activity and “half-life”calculated.
- Comparison with experimental results.

Theoretical model for collecting radioactivity on the wire.

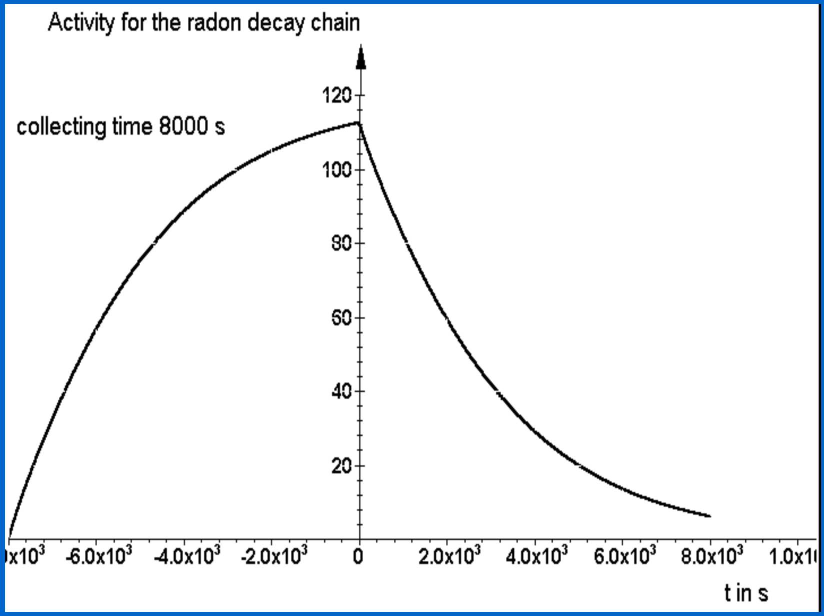
- $n_i \sim t_i$
- $d\,n_i \sim n_i \; dt$
- $d\,n_i = k * t_i * dt$

- The number n_i of ions in air is proportional to their half-life t_i because there is radio-active equilibrium between mothers and daughters.
- The number $d\,n_i$ of ions collected in time-interval dt is proportional dt and n_i

Calculating the change of n_3 on the wire

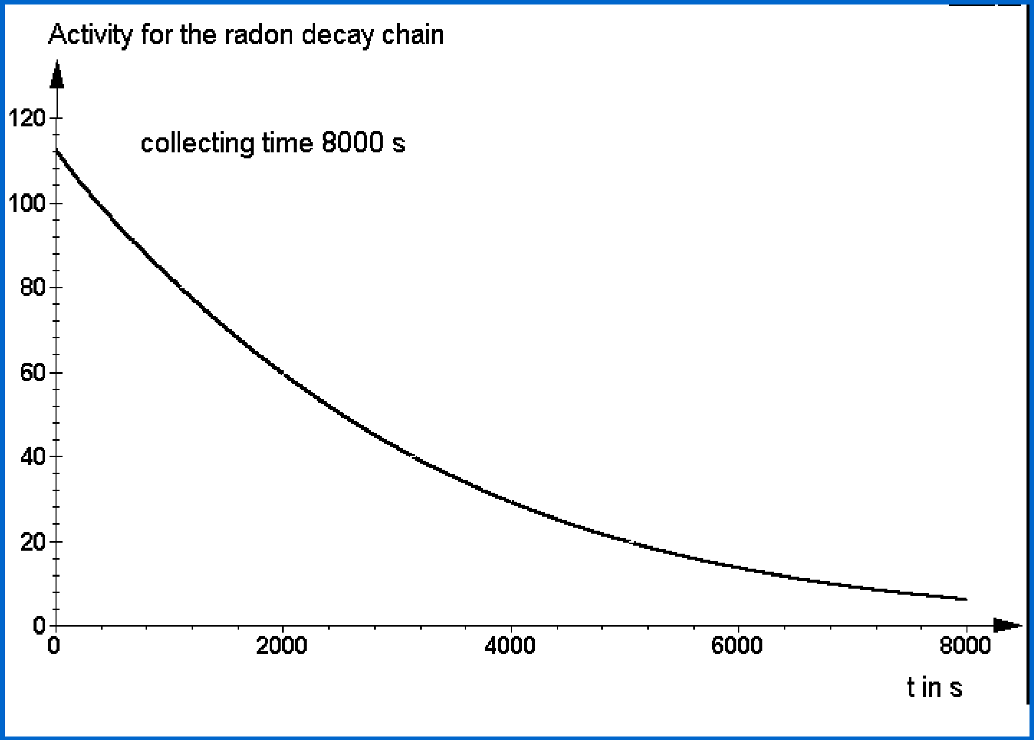
- Collecting from air $d\,n_3 = k * t_3 * dt$
- plus decay from mother $+ n_2 * \ln(2) / t_2 * dt$
- minus decay to daughter $- n_3 * \ln(2) / t_3 * dt$
- Number $n_{3new} = n_{3old} + d\,n_3$

Modelling radioactive decay



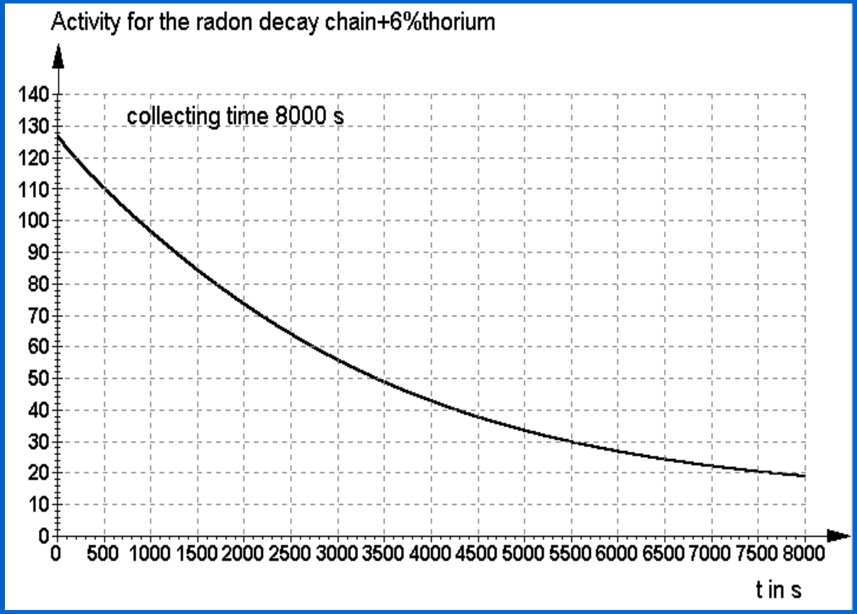
- $t < t0$ voltage -5 kV , collecting progeny nuclides from air, simultaneous decay
- $t = t0$ no voltage, wipe off the wire
- $t > t0$ only decay in the sample

Modelling radioactive decay



- t > t0 only decay in the sample
- half-life 35 min
- From experiment 44 min.
- Difference of 20%

Modelling radioactive decay of radon with about 6% thorium

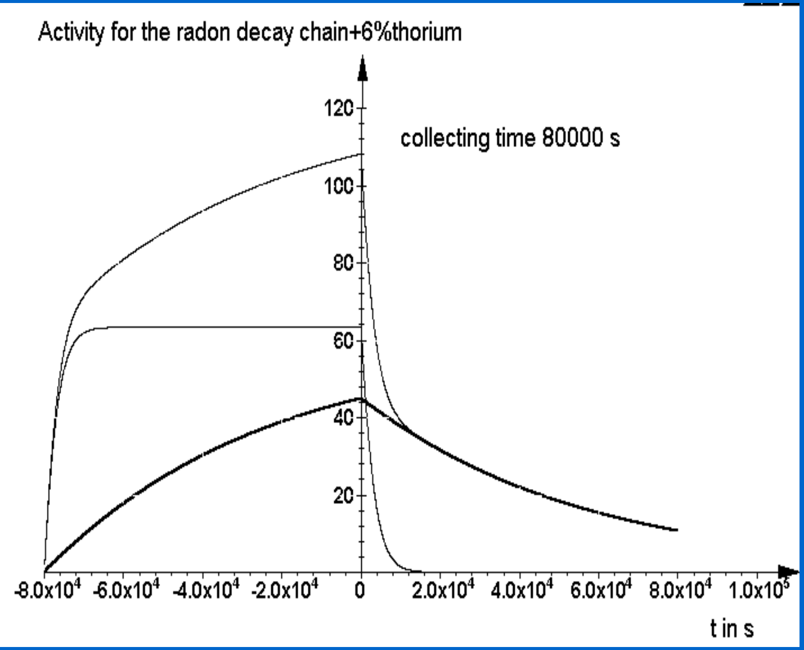


- The thorium progenies contain nuclides with larger half-life.
- half-life about from simulation 44 min
- from experiment 44 min.

Gamma -ray spectroscopy

From analysis of γ-decay (collecting 22 hours) the proportion of the uranium decay chain to the thorium chain should be about 60% to 40%.

Modelling radioactive decay of radon with about 6% thorium



- For this long time collection (22 hours) we compare the fraction of radon and thorium-activity from simulation.
- Also from simulation the fraction is about 60% to 40 %

Conclusion

- The assumption 6% Thorium which seemed to be arbitrary was approved,
- experimental and theoretical values harmonise perfectly.