X-RAY AND γ-RAY ABSORPTION IN MATTER

REFERENCES

1) K. Siegbahn, *Alpha, Beta and Gamma-Ray Spectroscopy,* Vol. I, particularly Chapts. 5, 8A.

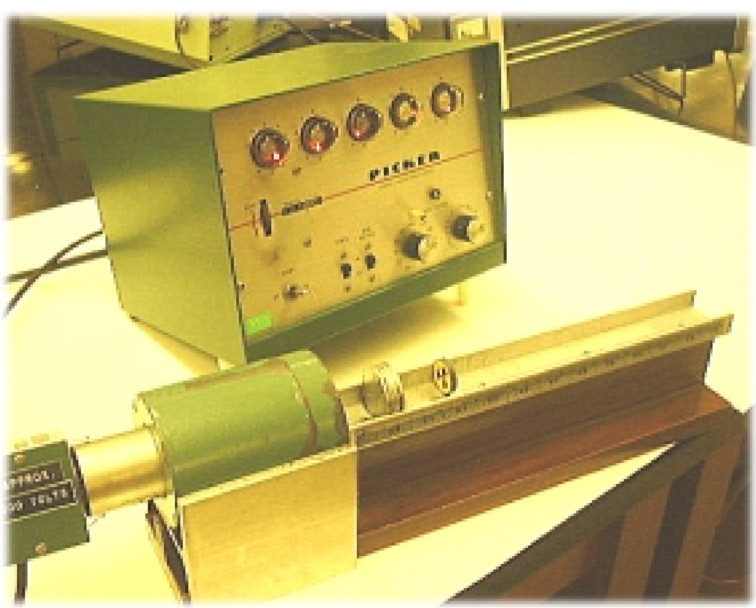
2) R.D. Evans. *The Atomic Nucleus*. McGraw-Hill, Toronto, 1955, pp. 711-718.

3) G.F. Knoll, *Radiation Detection and Measurement*, 2nd edition. John Wiley & Sons, Toronto, 1989, pp. 54-57 and 74-76.

SPECIAL NOTE ON SAFETY:

See *HEALTH AND SAFETY IN THE LABORATORY* in the **Laboratory Manual** with regard to handling radioactive materials and lead. In particular, note the following cautions on radiation: The sources we use in the lab are weak, so that when properly used, they subject the user to a small fraction of the radiation one receives in every-day life. However, as with any toxic material, it is important that you minimize the exposure you receive as any exposure does damage (be it small) to your body. Thus, place the sources you are using in a location away from yourself and other persons. Total radiation exposure is proportional to the source strength, the time you are exposed and a distance factor which for gamma rays drops off as the inverse square of the distance, and for alphas and betas, even faster.

INTRODUCTION



An X-ray or γ-ray travelling through matter can interact with the neighbouring atoms, often leading to its absorption. The probability of such an interaction is linked to the atomic structure of the material (and sometimes also to its molecular structure). The whole field of radiology rests on this variation in the X-ray or γ-ray absorbing power of different elements (namely the calcium of bones and the carbon and oxygen of soft tissues).

The aim of this experiment is to study the absorbing power, at different X-ray or γ-ray energies, of a variety of materials.

NOTES ON THE NUCLEAR COUNTING EQUIPMENT USED

THE GEIGER-MÜLLER TUBE.

A GM tube is a gas-filled metal chamber containing a thin central wire; a positive high voltage is applied between the central wire and the outer metal cylinder. A X-ray, γ- ray, or a charged particle traversing the chamber ionizes the gas, producing free electrons, which are accelerated toward the central high voltage wire. The electrons in turn collide with other gas molecules producing more ionization, and a large gas discharge occurs which produces a current pulse in the GM tube. This pulse is fed to the scaler, which counts pulses above a certain threshold, determined by the discriminator. In the proper operating region, the pulse is independent of the energy of the initiating particle.

If the voltage is increased from a low value, the counting rate increases rapidly then reaches a plateau. At the upper end of the plateau, the counting rate increases very rapidly, due to multiple pulses from one particle, and eventually a continuous discharge occurs. If a tube is operated in this region, it is soon ruined, so take care!!

THE PICKER SCALER

This provides a high voltage power supply for the Geiger-Müller tube and also counts the pules arriving from the GM tube. The Picker scaler block diagram is shown in Figure 2. All the components inside the solid line are inside the box of the scaler. The four connectors at the back of the scaler corespond to those labeled in Figure 2.

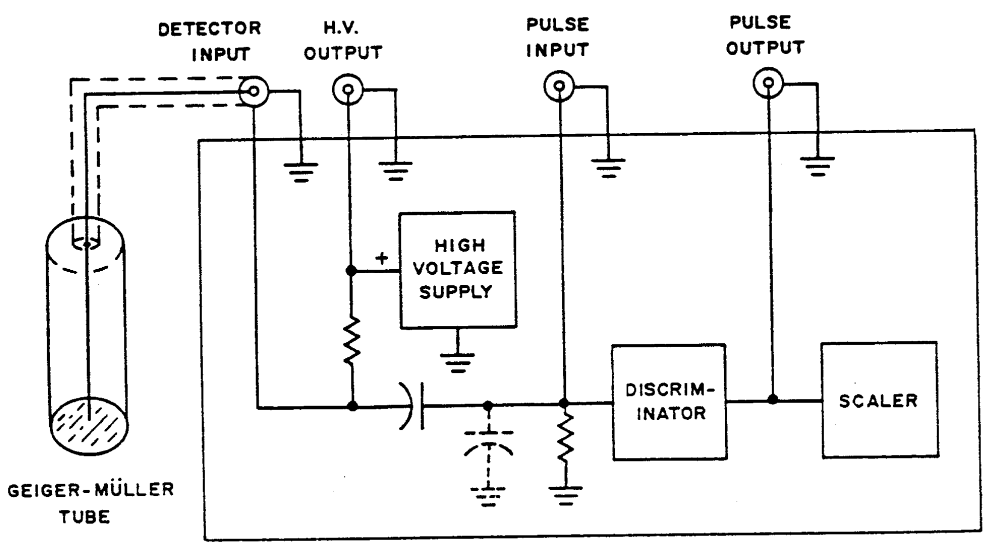


Figure 2.

EXERCISE

Connect the Geiger-Müller detector's high voltage cable to the scaler connector labeled *detector input.* Initially set the high voltage at 1000 Volts. Turn on the high voltage supply and the Picker scaler power switches.

Using a ^{137}Cs gamma source (γ--ray energies 0.662 MeV and 0.032 MeV) observe the pulses from the detector on an oscilloscope. (You can borrow an oscilloscope from the **R**esource **C**entre when needed. The scope should be plugged into the *pulses input* connector on the back of the scaler. If you have trouble triggering the oscilloscope, consult a demonstrator.)

CAUTION: Some of the Picker scaler connectors have high voltages on them, sufficient to damage an oscilloscope input. Be extra careful in connecting the oscilloscope to the *pulse input* terminal. Moreover, connect the oscilloscope to the Picker scaler *pulse input* terminal only after the Picker scaler has been set into operation. Also, do not switch the picker scaler high voltage setting while the oscilloscope is connected. When in doubt, consult a demonstrator.

Note the effect on the pulses, of moving the source closer to and farther from the detector. Note the randomness of time of arrival of the pulses. Note the rise and fall times of the pulses. Note the effects on the pulses of changing the high voltage. Be sure you understand what you are observing. If you don't, consult a demonstrator.

There should be pulses of various voltages present. It is primarily the largest voltage pulses that correspond to the Cs gamma-rays. Due to the presence of the discriminator in the scaler these pulses will not be counted by the scaler if the high voltage is below a certain threshold. Ideally, we would like to set the high voltage just slightly above this threshold. Measure count rate as a function of high voltage setting for voltages between 600 and 1100 volts (use 20 volt steps, and plot your results as you take them). Watch for a plateau region to appear, and take a couple of readings into the flat part of the plateau; do not go any further into the plateau region than necessary, and NEVER exceed 1200volts. Set your high voltage about 50 volts above the knee at the start of the plateau for the rest of the experiment.

NOTE: Excess voltage will damage components in the detector.
Do not apply more than 1200 volts.

EXPERIMENT

For a monoenergetic, collimated X-ray or γ-ray beam, the intensity of radiation passing through an absorber is:

$$I(x) = I_o e^{-\mu x}$$

where: I(x) =transmitted beam intensity
I_o = beam intensity if no absorber is inserted between source and detector
μ = linear attenuation coefficient (depends on material and photon energy)
x = thickness of absorber

As for other nuclear-physics experiments, a major part of the uncertainty in the counting is statistical: the standard deviation for an observation of N counts is $\sqrt{N}$ counts.

Arrange your apparatus as in Figure 3.

Measure the background rate (it should be subtracted from any subsequent measurement). Then, measure the count rate for different thicknesses of a given material. Repeat for different materials.

Compare the mean free paths λ, which are given by $1/\mu$ and try to relate them semi-quantitatively to some material properties (density, atomic number, etc.). A possible extension of this experiment would be to use as an absorber a mixture of materials.

A suitable geometrical arrangement of source, collimator, absorber and scintillation detector is shown. This arrangement tends to minimize the effects of scattering in the absorber.

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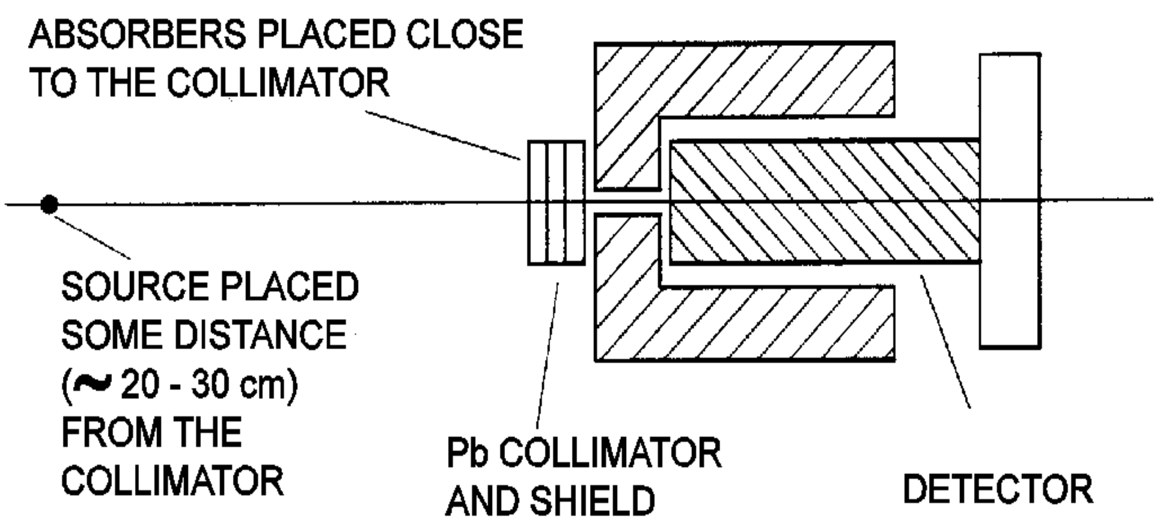

Figure 3.